Cyclopedia of American Agriculture

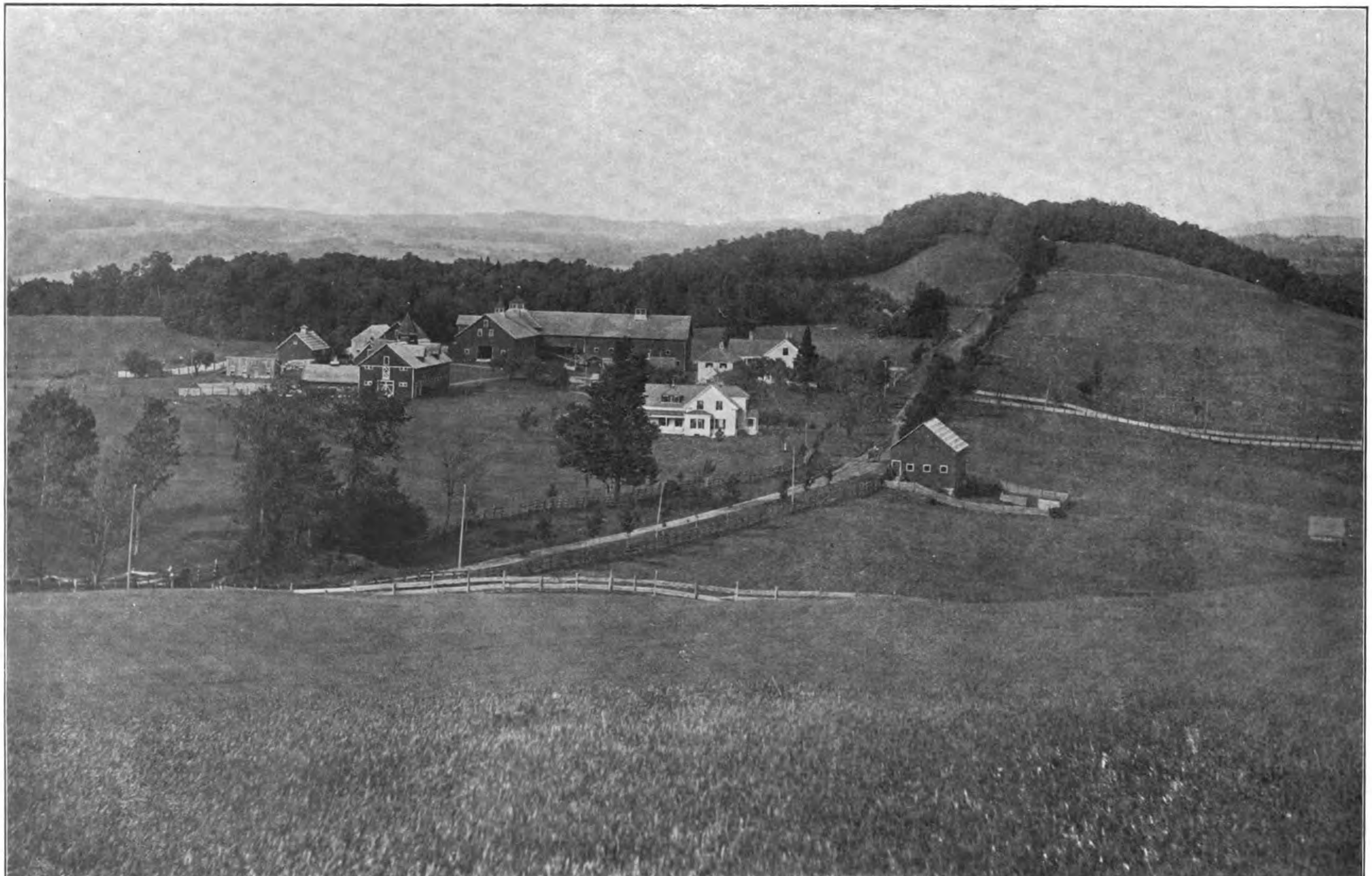

Plate I. The hills of New England. Mountain View Farm, Elmer A. Darling, Burke, Vermont

CYCLOPEDIA OF AMERICAN AGRICULTURE

A POPULAR SURVEY OF
AGRICULTURAL CONDITIONS, PRACTICES AND
IDEALS IN THE UNITED STATES
AND CANADA

EDITED BY
Liberty Hyde
L. H. BAILEY

With one hundred full-page plates and more than two thousand
illustrations in the text

IN FOUR VOLUMES
VOL. I—FARMS:
REGIONS FARM PLANS
SOILS ATMOSPHERE

New York
THE MACMILLAN COMPANY
LONDON: MACMILLAN & CO., LTD.
1907

Set up and electrotyped. Published February, 1907

Mount Pleasant Press
J. Horace McFarland Co.
Harrisburg, Pa.

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EDITORIAL STATEMENT

It is now several years since this book was projected and announced, when the Editor was little engaged with administrative affairs; but it was less than two years ago that any opportunity seemed to present itself to fulfil the contract with the publishers. The first manuscript was sent to the printer February 3, 1906; the last proofs in Vol. I were received December 11, 1906. This volume is now published on February 20, 1907.

It is not the purpose of such a book as this to mark new paths in special subjects, but only to bring together in one compendium some of the most significant facts and opinions that are now current. Free use has been made of all published data that is relevant and available, with the intention always to give full credit to the author. A great storehouse of information is presented to the public in the publications of the agricultural experiment stations and colleges, of the national Department of Agriculture, of the United States Census Bureau and of other institutions, from which all may freely draw. To this great repositorium, the farmer, editor, author, speaker and teacher will go with ever-increasing freedom and confidence for his facts; and this public treasure-house will be a pride and glory of American agriculture.

It is impossible, in such an undertaking as this, to mention specially the names of all the persons who have contributed in many helpful ways. Acknowledgement must be made, however, to two painstaking and capable young men who have been employed continuously on the work,—Albert R. Mann, B.S.A., secretary, and W. C. Baker, B.S.A., artist. They have given their best effort to make the work reliable and interesting. The editors of agricultural journals, farmers, teachers, experimenters, publishers, all have responded with help in a way that the Editor really had no right to expect, and to them is mostly due whatever may be useful in the work. Special acknowledgement should also be made of the liberal policy of the publishers of the Cyclopedia, The Macmillan Company, who have coöperated in every way to make the work creditable.

In order to fix responsibility, it should be said that all unacknowledged articles are written by the Editor.

The material for the illustrations has been collected from great numbers of sources. Every person to whom application has been made has contributed freely. The Editor is under obligations to Dr. Bartholomew for permission to make adaptations of many special charts from his Atlas of Meteorology. The Sanders Publishing Company gave permission to adapt or redraw cuts of farm buildings and appliances. Other publishers have granted similar favors. Much use has been made of pictorial matter in many publications of the United States Department of Agriculture. In the chapters on buildings, water-supplies and rural art, some of the cuts are reëngraved from Cornell publications, from which, also, two or three authors have rewritten and adapted personal articles. Pictures from the publications of Illinois, Maine, Ohio and Rhode Island experiment stations have been adapted for use in the chapter on fertilizers. Publications of many other stations and institutions have also contributed. In the chapters on tools and machinery, the publications of many manufacturers have been drawn on freely for pictures.

The Editor desires to be apprised of any errors or omissions that may come to the reader's attention. The manuscripts have been edited with care. All articles have been read in proof at least twice by both the Editor and his secretary. Every author has also seen his article three times in proof, and no changes have been made in the articles after the last proof was returned. Proofs have been read also by specialists other than the authors. Yet it is too much to expect that errors have been avoided.

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Cyclopedia of American Agriculture

IF an intelligent person were to request instruction in agriculture, his adviser would refer him to persons who are best qualified to speak on the different phases of the subject. The adviser might be so fortunate as to be able to bring these experts together on consecutive evenings. Each person would speak for his own subject, the others setting their observations, experience and opinion against his. Perhaps this seminar would be so organized by the person-in-charge as to develop the general subject in logical and progressive sequence. The hearer, for whom the seminar was arranged, would not be clear on all the points and he might not always agree. He might even be confused by different doctrines. But he must have the different views if he is really to know the subject; and in time, if he is an able man, he will develop a body of philosophy of his own.

It is not often, however, that the enquirer could have the privilege of a seminar of experts appearing in person. But these experts might be willing to put their views to paper, consigning them to the person-in-charge to be presented in an orderly way; and this person-in-charge might go so far as to print these papers in a book for the benefit of any man who was inclined to read them.

In putting together such a collection of papers, an editor might proceed on either of two theories: (1) to make a work in which all the data are examined, all the conclusions verified, all the theories tested, and all discrepancies eliminated, by the editor himself or by a board of review; (2) to analyze the subject in a general way and to organize it, but letting every contribution stand for itself, resting on the authority of its author. The first plan would result in an impersonal digest: the book would be concrete, homogeneous, definite, and would be said to be practical. The second plan would result in a personal collection: the book would be a thesaurus or treasury, in which opinions would be expressed; and the author names would follow the titles, just as a speaker's name is always given when he addresses an audience.

The present Editor has chosen to make a book on the second plan,—to make a popular cyclopedia (covering the round of the subject, as the word signifies), setting forth the opinions and conclusions of the best men. He is not unwilling that it shall be in advance of the practice of the day, to the end that the farmer may attain to it. He has had no idea of making a book of ready reference, nor, on the other extreme, of making a collection of monographs, nor of writing a treatise. It is hoped that the book will express the spirit of all good new teaching, and that it will be interesting enough to afford evening reading for the family fireside.

From all this it follows that there is no disadvantage if the authors do not all teach alike, or if one article now and then overlaps another. It is intended that there shall be no spirit of finality in the book. If any subject is in doubt, the doubt should be expressed. There is no reason why the reader should expect exact prescription on all matters. Teachers have all along made the mistake of trying to give the farmer only positive and indisputable information, laboriously sorting such bits of information out of the great store of developing and living knowledge, until they have bred a spirit that asks only for formularies on particular problems. The good teacher will often do no more than to suggest a line of thought or a method of enquiry.

The educated man is much more than a well-informed man. The only abiding teaching is that which tries to make the learner to understand, to appreciate the processes, to develop a kind of action and application for himself. The very doubts and uncertainties are themselves worth the while, for they are a part of life.

At this time there is special need of a comprehensive work, since the interest in agriculture is increasing rapidly and the emphasis is likely to be placed on incidental or even irrelevant features. Agriculturists themselves are conscious of a new pride of calling and are beginning to see their way out of difficulties. City men are looking as never before to the country for homes, to farm land as investment, and to farming as a business. There is every prospect that this latter interest will grow still more rapidly for a few years. Much of it is genuine and steady, and will stand for progress. There is danger that this interest may be too much influenced by books on very special subjects and by particular kinds of teaching. Of course, every special subject should have its treatises, but the reader should also know the relation of it to the general body of agricultural knowledge and philosophy. All knowledge and practice should form part of a system.

The Editor has in mind much more than the mere occupation of farming. Agriculture is primarily a business; but it also develops homes on the very land that it occupies; and both the business and the homes contribute to the character and the weal of the neighborhood and the state. The whole sphere of country life, so far as it is founded on the soil, may well be presented consecutively, even though the effort is inadequate at every point. It is conceived that the intelligent enquirer, who is willing to take the time to understand what agriculture is and what it signifies, will want to know first the general extent and character of it, and will then request advice on the way in which a farm should be projected and organized, and on what principles the homestead may be developed. He will then want advice on the technical practices, on growing crops and animals; and it is to be hoped that he will also ask for some discussion of the interrelationships of the farm and the community.

The first volume contains three kinds of topics: (1) accounts of agricultural regions; (2) the general layout and organization of a farm; (3) the larger environments that determine the life and character of plants and animals. These three sets are not necessarily parts of a single volume or exposition; but the second set naturally follows the first, and the third should follow the second; and the three together comprise introductory matter, and they constitute such a division of the entire field of the Cyclopedia as conveniently to be bound together. The third set divides itself readily into two substantially coördinate parts,—the soil environment and the atmosphere environment,—and they are therefore treated separately.

The second volume is to be devoted to crops, the first part being an exposition of some underlying principles and considerations, and the second part being an alphabetically arranged discussion of the different kinds of crops.

The third volume is to be devoted to animals, following the method of the second volume; and many animals aside from those ordinarily associated with farm operations are to be discussed.

The fourth volume will take the broadest field of all, discussing the farm and the community as expressed in history, biography, bibliography, education, statistics, economic and social questions.

The main purpose of the Cyclopedia, in all these articles and volumes, is to maintain in the reader the habit of looking at a question or problem rationally, without prejudice, free from preconceived notions or inherited opinions,—that is, to look at it scientifically, reasoning logically from the evidence.

PART I

THE AGRICULTURAL REGIONS

The territory of this book is North America north of Mexico, although the most important of the tropical islands with which the United States holds governmental relations receive incidental treatment. This continental territory includes the United States, the Dominion of Canada, the Colony of Newfoundland.

There is no geographical or agricultural distinction between the United States and Canada except such as arises from difference in latitude. The area of Canada is 3,448,170 square miles; that of the continental United States, including Alaska, is 3,560,922 square miles.

The natural agricultural adaptabilities of a continent are determined by soil and climate. The soil features are likely to be complex and usually not regional, and are incapable of rapid treatment in generalities. They are not determined by their relative place on the earth's surface.

Climate in its agricultural relations is largely a question of latitude, elevation, rainfall and sunshine. Latitude and elevation are expressed chiefly in terms of temperature.

A relief map of North America, showing elevations and drainage systems, throws into bold display the main agricultural land masses. Plate II makes such an exhibit. The shadings mark the series of elevations. The jet-black shade indicates elevations above 10,000 feet: these elevations occur as isolated points in the Rocky mountain and Sierra region, from New Mexico and southern California to Alaska. The gray-black regions include elevations between 5,000 and 10,000 feet: they comprise

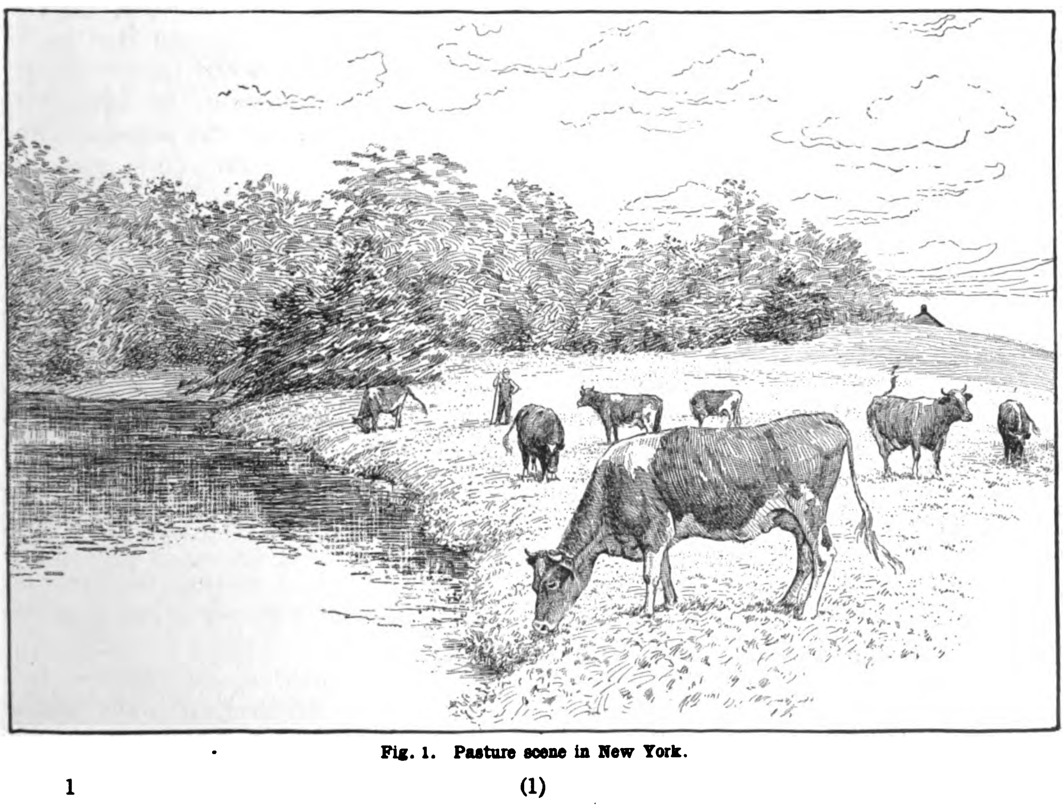


Fig. 1. Pasture scene in New York.

mountain masses in the West, isolated points in the Appalachian System, and small areas in the extreme northeastern arctic region. The dark gray areas are elevations between 1,000 and 5,000 feet: they comprise about one-third of the continent, and afford, in temperate regions of sufficient rainfall, vast reaches of natural grazing lands, with large parts also adapted to tillage. The light gray regions are between 100 and 1,000 feet: this elevation includes immense areas in arctic and sub-arctic regions, and also the great Mississippi valley, which is probably the largest continuous agricultural area on the globe of equal fertility and productiveness. The white areas are seacoasts, reaching to an elevation of 100 feet: these are small in extent; they are of recent geological origin, being now in process of natural reclamation from the sea; so far as they are agricultural, they are adapted only to very special uses.

The general physical and geological features of the continent, as represented on the relief map, are explained for this occasion by Professor Ralph S. Tarr: "The topography of North America may

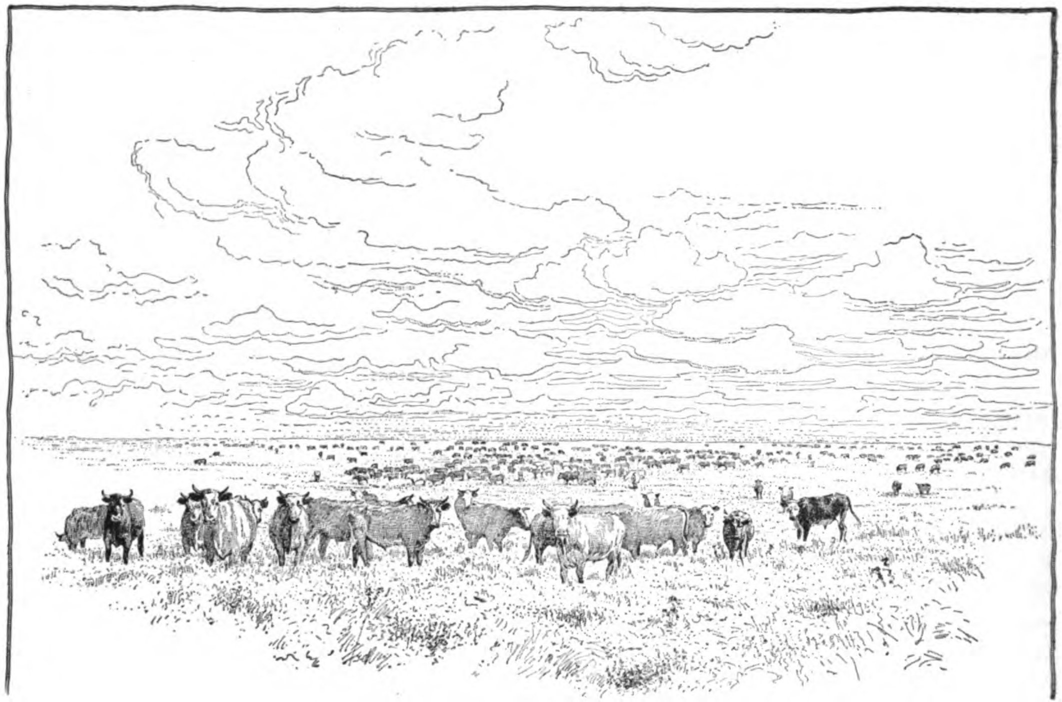


Fig. 2. Pasture scene on the great plains.

be grouped in five great divisions, as follows: — (1) *the Coastal Plain*, a lowland region on the Atlantic coast and swinging along the shores of the Gulf of Mexico; (2) *the Appalachian Belt*, a low mountain region extending from Alabama to Newfoundland and Labrador; (3) *the Central Plains*, occupying the Mississippi valley region, and stretching from the Appalachian to the Rocky mountains and far northward into Canada; (4) *the Western Cordilleras*, including the Rocky mountains, Basin ranges, Sierra Nevada-Cascade mountains, Coast ranges, and the intervening plateaus, extending, under other names, from southern Mexico to northern Alaska; (5) *the Canadian Region*, a low hilly region in northern Canada extending westward from the Labrador coast to the Great Plains.

"The geology of each of these provinces is very complex and difficult to characterize in a few words. The coastal lowland, the simplest of all the provinces, is a low, narrow coastal plain, made of nearly horizontal clays, sands and gravels often not yet consolidated. So recently has this been added to the continent by uplift that the streams have as yet only imperfectly drained it; and in its sediments are fossils of species still living in the neighboring ocean. Its damp coastal part is adapted to rice culture, and its sandy soils to the long-leaf pine.

"Back of the coastal plain is a low hilly region, called the piedmont plateau, which extends up to the base of the Appalachians. Its rocks are on the whole of ancient date, belonging to the paleozoic and pre-paleozoic age. They have been profoundly folded and greatly worn, so that they are now

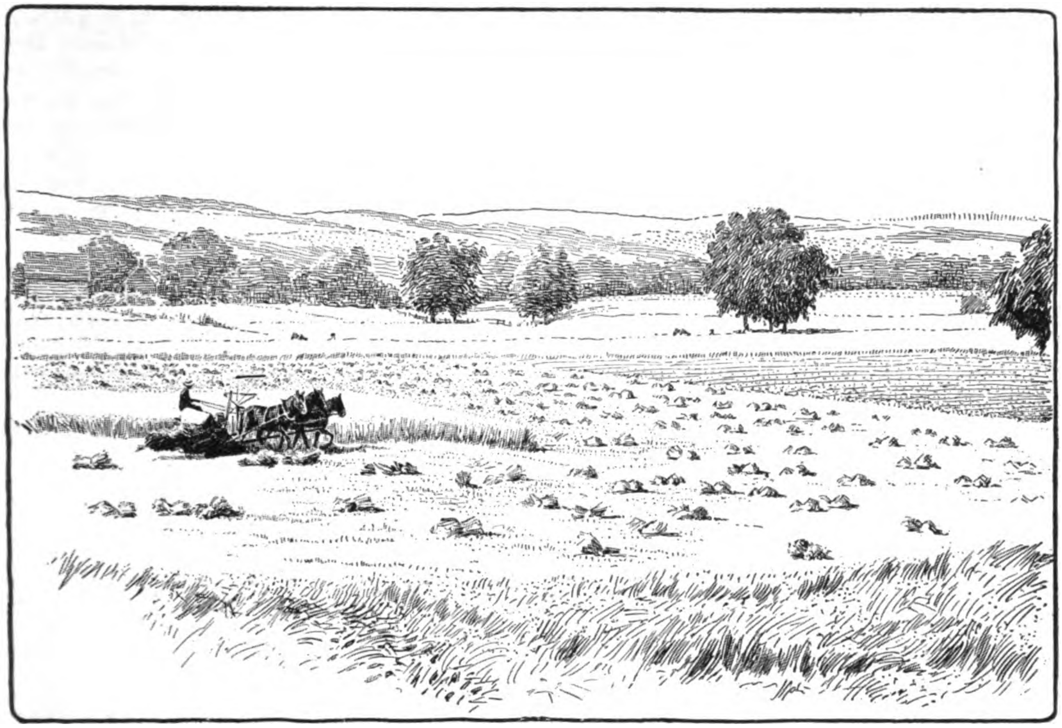


Fig. 3. Harvest scene in Pennsylvania.

reduced to an almost plain surface of gentle undulation. This is in reality a worn-down mountain region, and its fairly even surface, deep soil and favorable climate suit it to the culture of cotton and tobacco.

"The Appalachian Belt, next west of the piedmont, varies in geological structure, but is almost everywhere of paleozoic or pre-paleozoic age. On the whole, the rocks are profoundly folded and faulted, and they are everywhere deeply eroded, giving rise to a very rugged topography. On the western margin the rocks have not been folded, but erosion has so sculptured this region that it is often called moun-

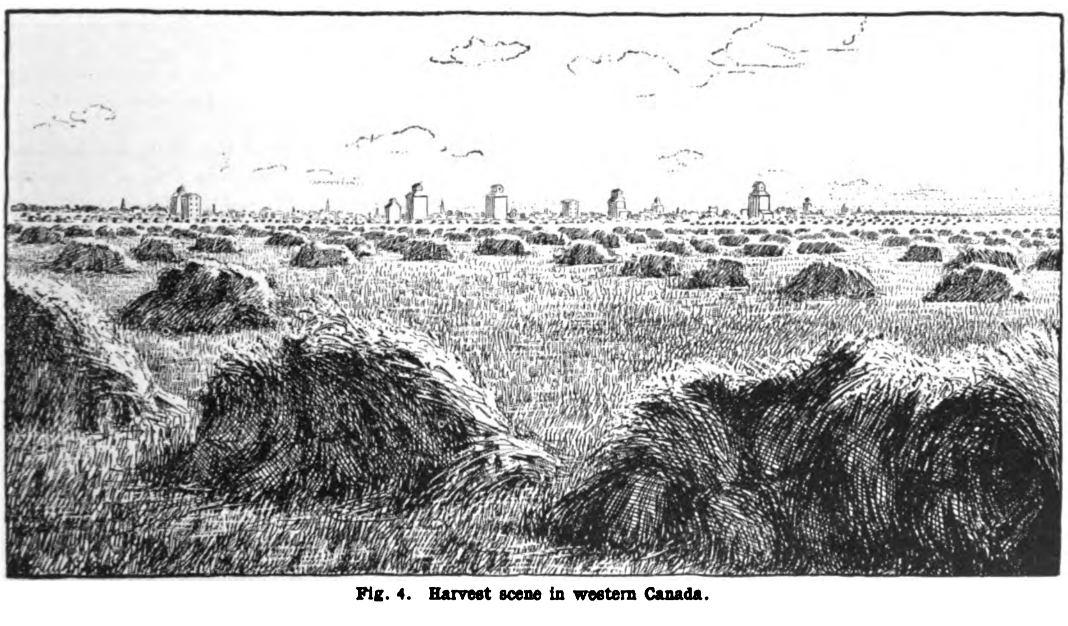


Fig. 4. Harvest scene in western Canada.

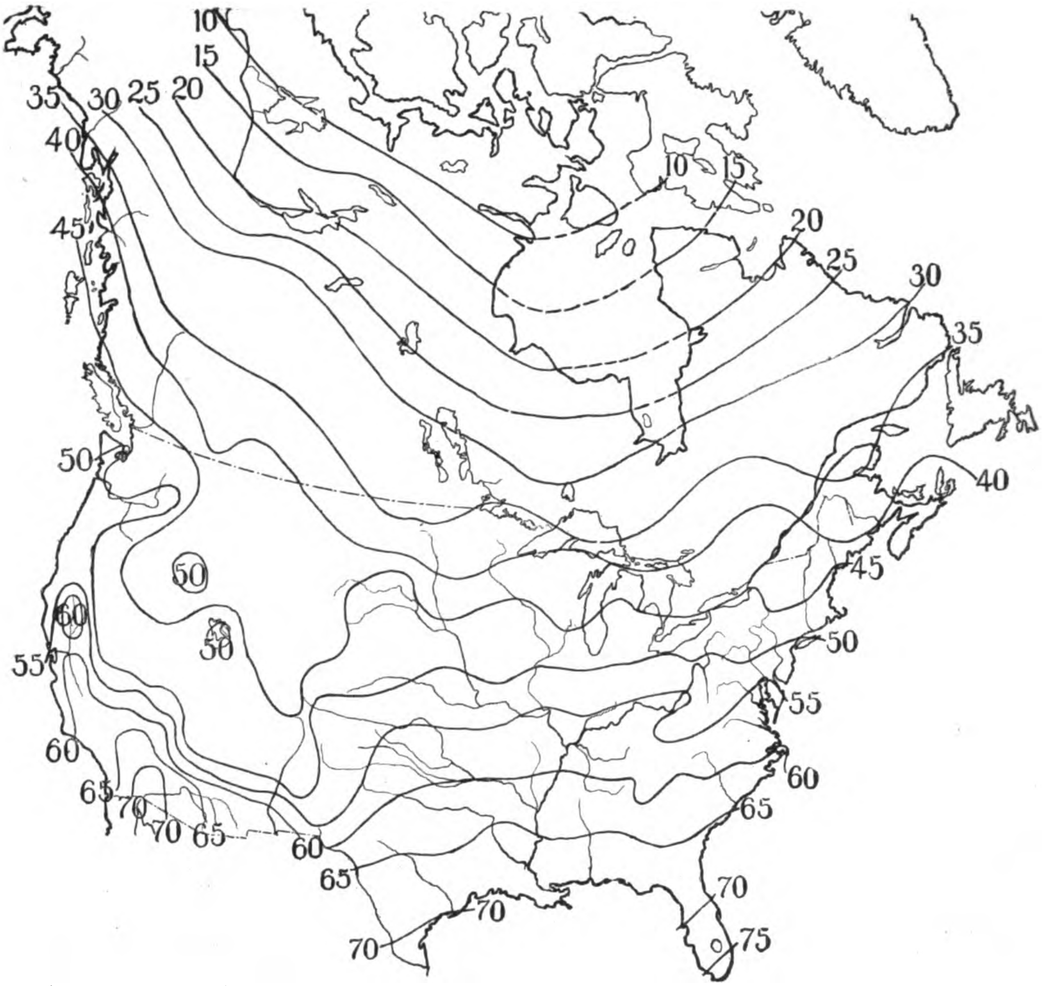


Fig. 5. Mean annual isotherms of North America. (Combined from Chart 20, United States Weather Bureau, and Weather Map of Dominion Meteorological Service.)

tain, as in the Catskill and Alleghany sections, which are really dissected plateaus. Taken as a whole, this province is too rugged for agriculture and much of its surface is therefore still timber-covered ; but the valleys, notably the Saint Lawrence, Connecticut and Shenandoah, are often broad, gently sloping, fertile, and well suited to agriculture, and consequently are the seats of important agricultural industries.

"The Canadian Belt is a worn-down mountain region of ancient rocks, in the main too far north for farming, but bearing a great wealth of forest products in its central and southern parts. In its extreme southern and southwestern part this region is in contact with both the Appalachian and Central Plains areas, and there it is often so low, and its topography so moderately irregular, that it is adapted to agriculture. This province extends into the United States along the shores of Lake Superior in northern Michigan, Wisconsin and Minnesota, where it supplies the iron for which that region has become famous.

"South of the Canadian Belt and west of the Appalachian mountains is the largest and most important of the five provinces,—the Central Plains. Low in the Mississippi valley and high (5,000 to 6,000 feet) near the base of the Rocky mountains, this belt extends with remarkably level surface from the Coastal Plains of the Gulf shore far northward into Canada. Only in three or four places, notably the hilly regions of central Texas, the mountains of Indian Territory, the Ozark region of Arkansas and Missouri, and the Black Hills of South Dakota, is the surface broken by distinct uplifts where the older rocks have been upfolded into low mountain areas. Elsewhere the strata are essentially horizontal, the surface remarkably level, and the soil deep and fertile. In the east the strata are of paleozoic age, but in the Gulf states and near the Rocky mountains the strata are younger, notably of cretaceous and tertiary age. This province is one of the greatest grain-raising regions of the world; but in the West, generally speaking west of the 100th meridian, there is too little rainfall for agriculture without irrigation, and this, therefore, is primarily a range country.

"The geology of the Cordilleran region is very complex, including strata of all ages from archean to recent, in all positions from horizontal to strongly folded and faulted, and at all altitudes from below sea-level to the loftiest mountain peaks. In general, the plateaus are made of strata essentially horizontal, the mountains of highly folded and faulted strata. There is every kind of rock and, consequently, a great variety of soils. Here, however, alone of all the provinces, is found in great abundance volcanic rock with its fertile soil. Hundreds of thousands of square miles of country from Canada to southern Mexico are covered by volcanic outflows, the most extensive areas being in the valley of the Columbia and Snake rivers, famous for its wheat production. Much of this province is too rugged for agriculture; far more is too arid; and for these two reasons vast areas of it can never be utilized for farming. In western Canada and northwestern United States there is abundant rainfall; and throughout the area irrigation is employed in areas of ever-increasing extent.

"All of Canada east of the Rocky mountains, and all of the northeastern United States, from New England to western Montana have been invaded, in a recent geological period, by a great continental glacier, which has profoundly modified the topography in detail and imported soils of glacial origin. This glacial invasion covered all of New England, and the outer margin of the glacier extended westward across New Jersey, northern Pennsylvania, thence westward across southern Ohio, Indiana and Illinois to the Mississippi, thence northwestward approximately along the Missouri to the Rocky mountains. In the glaciated area most of the soils are either directly or indirectly of glacial origin and are very diverse from place to place. In the Cordilleran region, mountain glaciers occupied many of the valleys, and often descended to the mountain base and spread out over the plains or plateaus, notably in northern and western Washington."

The northern limit of agriculture on the eastern side of the continent may be set roughly at the fiftieth parallel. This limit bends rapidly northward midway of the continent, reaching the coast region of Alaska. It is approximately the annual isotherm of about 35 degrees. Fig. 5 exhibits the courses of the isothermal lines across the continent. In the northern part, they descend into the middle of the continent, but follow the general course of the parallels, although rising much higher on the western coast. The interior of this vast northern region is approximately level. Much of it is a region of permanently frozen subsoil and with bodies of water ice-filled for a good part of the year. Farther south the isotherms show the interference of mountain masses. There are sharp southward bends in the Appalachian region, and very complicated deflections in the Cordilleran region. On the west coast, the lines are opposed to the parallels of latitude, their positions being determined by mountain chains and Pacific ocean currents. The Pacific coast, therefore, has its own climates, wholly independent of regions east of the continental divide. The temperature factor in the distribution of crops is not well represented in annual isotherms, however, but rather in the ranges and distribution of temperature. The corn-belt and the cotton-belt, for example, do not follow annual temperature lines.

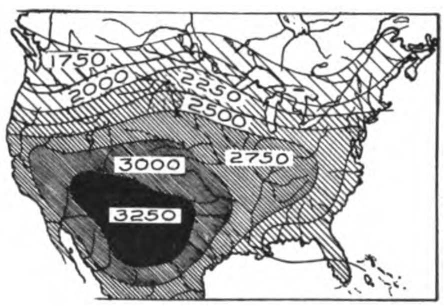


Fig. 6. Mean annual sunshine of Canada and the United States.—The figures indicate the number of hours of bright sunshine in a year. (Adapted from Bartholomew's Atlas of Meteorology.)

Closely associated with temperature are the sunshine percentages. Fig. 6 shows the leading areas. This map, by J. W. van Bebber, "is based on the data collected up to the end of 1895, mainly from Jordan photographic sunshine recorders, or from differential thermometers. The distribution is almost homologous to that in Europe. The sunshine increases toward the south and toward the interior, and the more elevated stations have less than those nearer the sea-level. The maximum sunshine is recorded in the north of Mexico, Arizona, Colorado and New Mexico. The sunniest month is May or June in the South, and July in the North, the reverse of what happens in Europe."

The precipitation in North America is greatly complicated by the physical configuration. Fig. 7 illustrates this. In the coast regions the oceans control the rainfall. The area of this dominance on the west coast is narrow, however, owing to the mountain barriers, that condense the moisture of the trade-winds. The great Mississippi valley is dominated by the Gulf of Mexico. The cyclonic movements sent northward from the Gulf are carried eastward by the prevailing winds; were it not for this dominance, the interior valley would be a desert. Between the region of Pacific dominance and Gulf dominance is an immense stretch of arid and semi-arid country. The chart (Fig. 7) shows that the isohyetal of 20 inches runs from Labrador southwesterly to the mid-continent and then turns abruptly southward to the Rio Grande. Other isohyetals of the eastern part of the continent follow a similar course. There are regions of high precipitation at various places along the Atlantic, the Gulf, and near the Great Lakes. In the western part of the continent, the precipitation-lines are local and complex.

The agricultural adaptabilities of the parts and regions of North America have not yet been the subject of careful scientific investigation. The available information is largely descriptive and statistical. Exact studies of the adaptabilities of soils, climates and regions to types of farming mark an advanced stage of agricultural effectiveness. Beginnings are being made in soil surveys and crop surveys. Persons who wish to inform themselves on the geography of agriculture in North America should consult recent books on physical geography; reports on the agricultural capabilities issued by some of the states; publications of the Bureau of Soils of the United States Department of Agriculture, and other publications of the Department; reports of geological surveys in Canada and the United States. A descriptive account of agricultural regions in both North America and South America may be found in Hunt's recent book, "How to Choose a Farm; with a Discussion of American Lands."

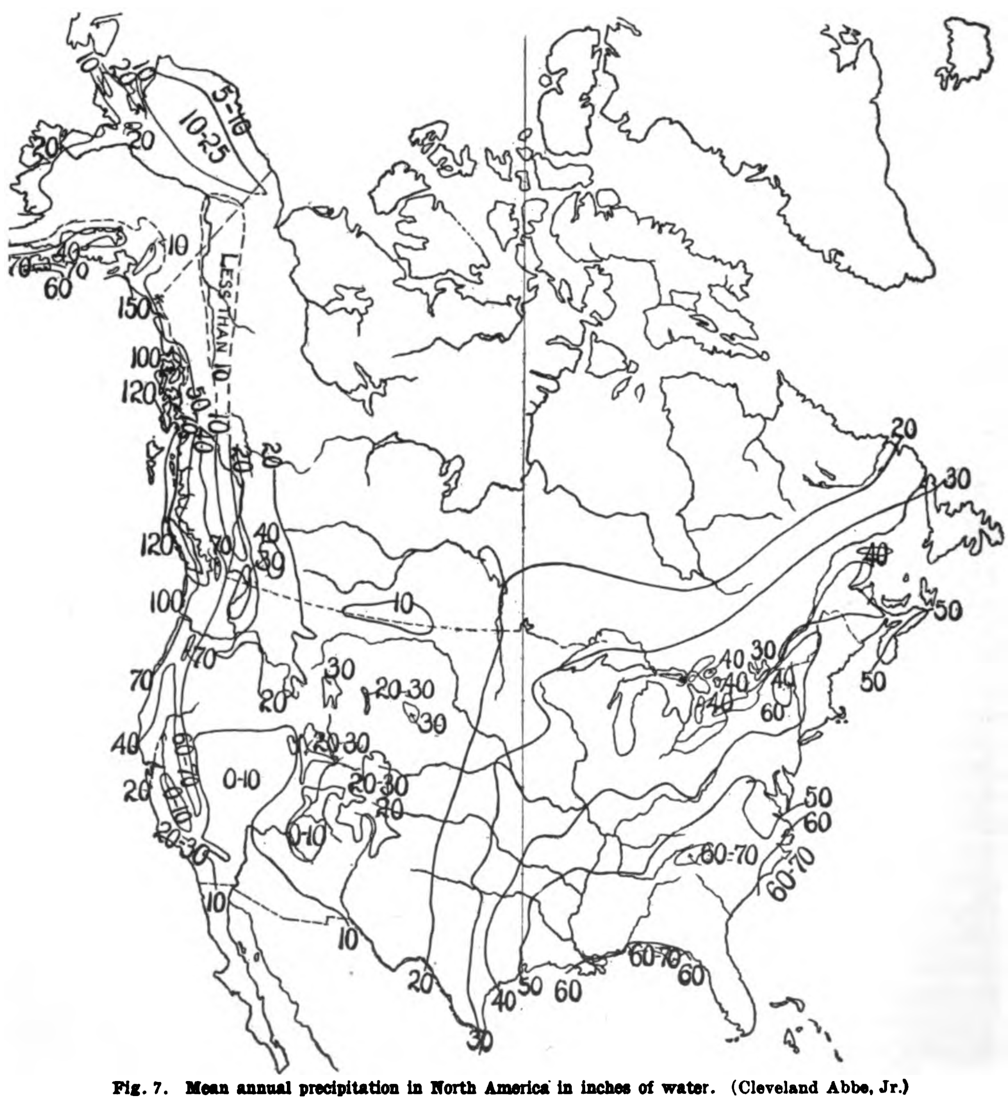
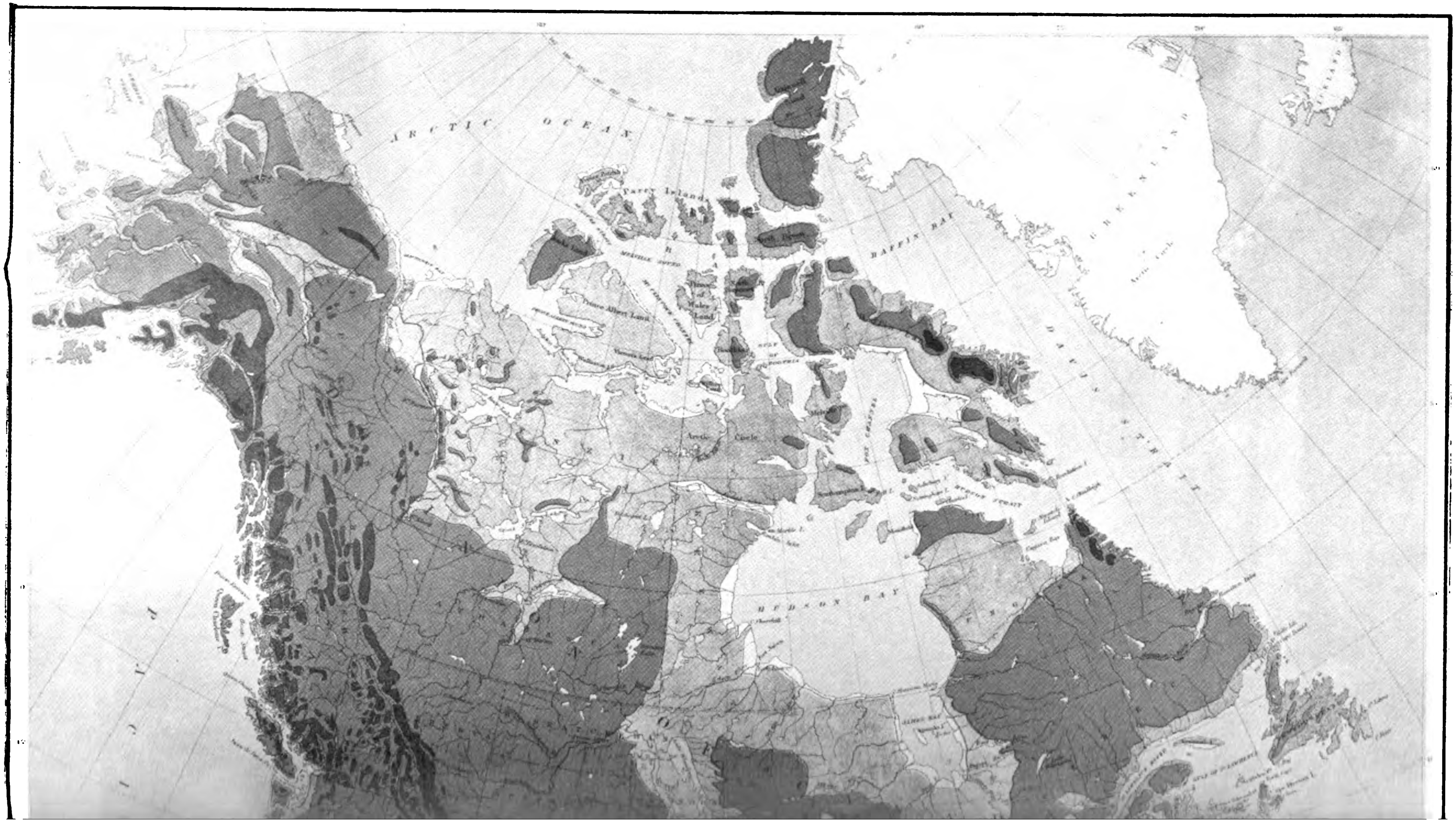


Fig. 7. Mean annual precipitation in North America in inches of water. (Cleveland Abbe, Jr.)


ARCTIC OCEAN
Parry Islands
BAFFIN BAY
GREENLAND
DAVIS STRAIT
HUDSON BAY
Arctic Circle
Prince Albert Land
JAMES BAY

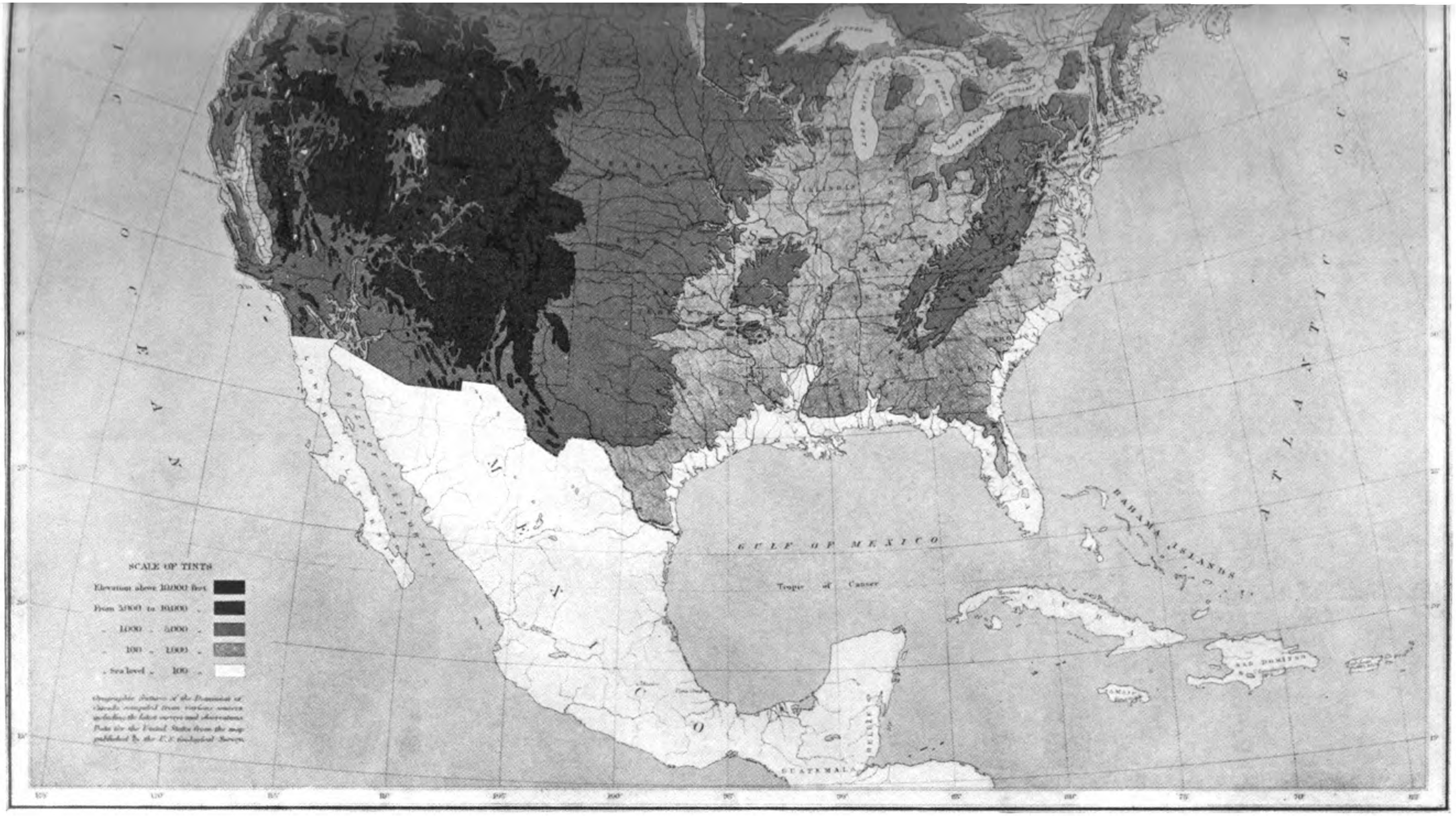


Plate II. Relief map of Canada and the United States, showing also the drainage systems. (Prepared by the Geological Survey of Canada, 1900.)

CHAPTER I

AGRICULTURE IN THE UNITED STATES AND CANADA

AGRICULTURE IS A SERIES OF OCCUPATIONS FOUNDED ON THE PRODUCTIVENESS OF LAND. These occupations may be only remotely related, as, for example, the growing of cut-flowers under glass and the raising of cattle on the plains. It is impossible, therefore, to describe any occupation as typical of agriculture. For this reason it is also impossible to prepare a homogeneous and consistent treatise on agriculture.

The persons that engage in agriculture are even more various than the occupations that they represent. In the United States these persons represent not only all nationalities, but also all ranges of inherited ideals and all epochs of colonization. It is impossible, therefore, to speak of "the farmer" as if he represents an isolated and typical element of society. The northeastern states owe their agricultural methods and ideas largely to the individualistic and democratic conceptions of the Puritans and to the transplanting of the grass-farming systems of England. The agriculture of the southeastern states was early influenced by the aristocratic conceptions of the cavaliers, and the southern type of society has been profoundly modified by human slavery; and the climatic conditions have developed an agriculture with cotton as its center. The southwestern and far western states and territories have been modified by Spanish ideas, with large holdings in a few families and a retaining peasant class; and the products have been secured from imperfectly handled lands and of such character as demanded the least expenditure of effort. This influence is rapidly passing. The settlement of the vast mid-continental region has called for marked re-adaptation of agricultural practice, and has produced what may be regarded as the closest approach to an American agriculture, in the extent of operations, the employment of machinery, and the emphasis of tillage. In immense territories the necessity of irrigation has developed another agricultural type.

The American is still a cheap-land farmer, for the most part. He has not become fixed to land in the way that the European farmer has. He is known by his freedom in moving from one piece of land to another. The most careful and exact farming begins to develop in old and perhaps even in difficult regions. It is significant that the recent marked rise in the prosperity of the farmer is coincident with the cessation of free homesteading on the public domain on a large scale, and with the consequent establishing of agricultural peoples.

This leads naturally to the suggestion that we are likely to look to Europe more than we have in the past for methods of studying agricultural questions. This is particularly true in the great field of farm organization, in which Americans have made few adequate studies as compared with the German and other writers and for which we have little consecutive and reliable data.

The area of farm-owned land in the United States is now practically coterminous with the limits of possible cultivation,—that is, all the area exclusive of inaccessible mountains and submerged and arid regions. This is well shown in Fig. 8, which is adapted from the Statistical Atlas of the Twelfth Census. Fig. 9, adapted from the same source, shows the general geographical movements of population and crops for a series of years.

Value of farm products per acre.

The effectiveness of farming cannot be measured by any single means or sets of figures. One of the common means of indicating it is in the value of farm products per acre of improved land. Judged by this standard, the states in which small areas are in cultivation under individual management are likely to show to best advantage. This may be because the farming is actually better in general, or because it

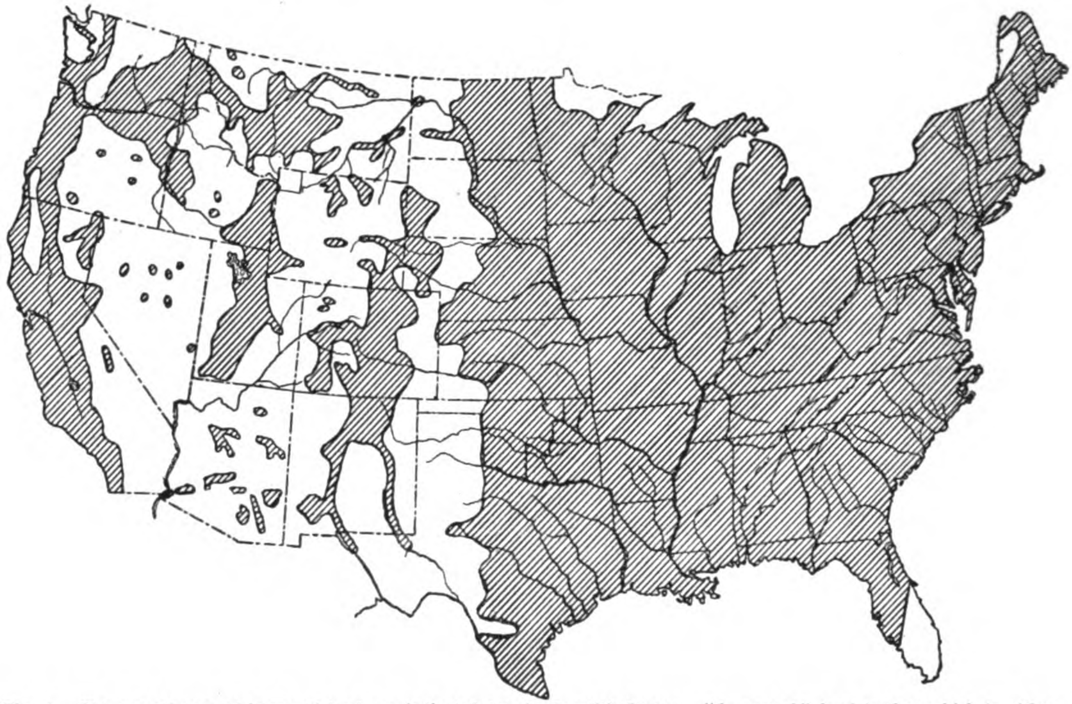


Fig. 8. The general area of improved land, as indicated by the Twelfth Census. "Improved" land is that which is either tilled or in permanent meadows, pastures and fruit plantations. The original map is in six shades of color, to show the proportion of improved land to total land area, in percentages of the land under cultivation in each county, ranging from one per cent or less to 75 per cent or more.

is possible to choose the land with special reference to the needs of the crop when fields are small, or because there is less loss in the crop in such fields. Following are figures from the Twelfth Census of values per acre:

Average Value of Farm Products per Acre of Improved Land.

	Products fed	Products not fed	Total
United States	$2 35	$9 07	$11 42
North Atlantic division	4 42	12 70	17 12
Maine	4 13	11 42	15 55
New Hampshire	5 58	14 78	20 36
Vermont	5 44	10 34	15 78
Massachusetts	6 40	26 34	32 74
Rhode Island	5 17	28 63	33 80
Connecticut	5 80	20 76	26 56
New York	4 07	11 66	15 73
New Jersey	4 35	17 73	22 08
Pennsylvania	4 32	11 42	15 74
South Atlantic division	1 34	8 75	10 09
Delaware	2 51	9 82	12 33
Maryland	2 49	9 97	12 46
District of Columbia	4 09	142 56	146 65
Virginia	1 29	7 29	8 58
West Virginia	1 48	6 66	8 14
North Carolina	1 21	9 51	10 72
South Carolina	0 99	10 83	11 82
Georgia	1 15	8 68	9 83
Florida	1 40	10 71	12 11
North Central division	2 56	8 06	10 62
Ohio	2 92	10 44	13 36
Indiana	2 91	9 35	12 26
Illinois	2 96	9 52	12 48
Michigan	3 12	9 30	12 42
Wisconsin	3 70	10 30	14 00
Minnesota	1 80	6 94	8 74
Iowa	3 41	8 81	12 22
Missouri	$2 53	$7 05	$9 58
North Dakota	1 07	5 60	6 67
South Dakota	1 19	4 67	5 86
Nebraska	2 06	6 76	8 82
Kansas	1 95	6 44	8 39
South Central division	1 56	9 55	11 11
Kentucky	1 54	7 43	8 97
Tennessee	1 80	8 56	10 36
Alabama	1 17	9 39	10 56
Mississippi	1 55	11 95	13 50
Louisiana	1 40	14 17	15 57
Texas	1 56	10 69	12 25
Oklahoma	1 47	6 77	8 24
Indian Territory	1 45	7 59	9 04
Arkansas	1 95	9 50	11 45
Western division	1 76	10 63	12 39
Montana	2 92	13 56	16 48
Wyoming	2 47	12 56	15 03
Colorado	2 72	11 81	14 53
New Mexico	3 17	27 89	31 06
Arizona	3 21	24 28	27 49
Utah	2 87	13 12	15 99
Nevada	2 75	9 05	11 80
Idaho	2 41	10 36	12 77
Washington	1 50	8 55	10 05
Oregon	1 86	9 58	11 44
California	1 13	9 88	11 01
Alaska	2 70	47 91	50 61
Hawaii	..	74 83	74 83

Capital invested in agriculture and manufacture.

The following table gives the number of farms and certain general statistics relating thereto as reported by the Twelfth Census of the United States, 1900. The word "farm" in this census signifies all separate tracts of land, regardless of size, or of the income therefrom, which required for their management the services of at least one person during the greater part of the year:

Number of occupiers (farms)	5,739,657
Land occupied (acres)	841,201,546
Land improved (acres)	414,793,191
Land in field crops (improved)—in hay and grain only (acres)	146,588,747
Value of lands	$13,114,492,056
Value of buildings	3,560,198,191
Value of implements and machinery	761,261,550
Value of live-stock	3,078,050,041
Total capital investment	20,514,001,838
Value of products (1899)	4,739,118,752

The population of the United States as returned by the same census was 76,303,387 persons.

The figures that follow will enable the reader to make comparisons with the capital invested in manufactures, as given by the Twelfth Census of the United States:

		1900	1890
Land		$1,027,453,140	$775,586,849
Buildings		1,450,495,991	878,570,737
Machinery, tools and implements		2,543,080,244	1,584,276,390
Cash and sundries (working capital)		4,796,405,424	3,286,722,510
Materials (cost)		7,345,413,651	
Materials purchased in raw state	$2,389,140,942		
Materials purchased in partially manufactured form	4,633,804,967		
Fuel, freight, etc.	322,467,742		
Gross value of products		13,004,400,143	9,372,437,283
Net value of products		8,370,595,176	

The leading crops.

Although agricultural occupations are so exceedingly diverse, it is nevertheless possible to throw them into a few groups. They may be classified in many ways. The following grouping may be useful for some purposes:

The grass-farming series, in which hay and pasturage are the keynotes. In the northeastern United States and eastern Canada, where this series reaches its highest development, these occupations develop an effective mixed husbandry.

The single-crop series, in which all the cropping revolves about one tilled staple as a king-pin. This series develops its own economic and social types. Characteristic examples of this are cotton-farming in the South, corn-farming in the central part, and wheat-farming on the northwestern frontiers.

The large-area grazing series, typical of new counties and cheap lands. It passes into other series, becoming part of them as the regions develop, although there are vast areas in the unirrigable West that will probably always be used for this kind of agriculture.

The forest series, which are at first the harvesting of native-grown woodlands, but which in time rest on the methodical growing of forests in the spirit in which other crops are grown. In the future, forest agriculture is likely to be a community or governmental effort. The native forest regions of the United States are shown in Fig. 10.

The intensive series, comprising small areas that are brought to very high states of productiveness. The crop-plan depends on the climate and the market. Usually it is some form of market-gardening. It is often asserted that high-class intensive farming is the final result of good agriculture; but such statements are not well considered.

The animal specialty series, in which particular groups or breeds of animals are made the center or sum of the activities. Special poultry-raising, horse-breeding, fish-culture, and the like, belong here.

High-class specialty farming, in which one product, or a series of products, is developed under the most perfect conditions of control, is likely to appeal to the novice as the first thing to do when undertaking a farming business; but it is usually the last thing to do, for such effort requires the highest degree of skill, which is developed only by well-trained and seasoned persons.

Some of these series are distinctly regional in the United States, as the grass-farming, grazing, and some of the single-crop types; all intensive and special types are likely to develop in any region, as they are controlled less by natural factors than by economic and personal ones.

The leading crops of the United States in 1905 measured by money value, as displayed by the Secretary of Agriculture, were as follows:

> Corn, 2,708,000,000 bushels, with a probable total value of $1,216,000,000. "No other crop is worth more than half as much."
>
> Hay, with a valuation of $605,000,000, due to high prices rather than highest yields.
>
> Cotton, including seed, with a value "expected to rise well toward $575,000,000."
>
> Wheat, 684,000,000 bushels, only once exceeded in the United States, and of the highest value ($525,000,000) ever produced.
>
> Oats, 939,000,000 bushels, which is 50,000,000 below the crop of 1902, which was the largest crop; value, $282,000,000.
>
> Potatoes, falling below the highest previous production, 1904, by 72,000,000 bushels, valued at $138,000,000.
>
> Barley, 133,000,000 bushels, with a value of $58,000,000.
>
> Tobacco, sugar-cane and sugar-beets, and rice, follow in order.

The acreage in improved land in farms classified by principal source of income on June 1, 1900, and the values of products for 1899, are given as follows, by the Twelfth Census; and also the acreage, production and value of eight specified cereals in 1899:

	Acreage	Value		Acreage	Value
Hay and grain	146,588,747	$1,240,978,449	Rice	462,676	$7,819,805
Vegetables	5,274,218	118,255,243	Sugar	1,032,117	40,804,284
Fruits	3,417,074	81,994,100	Flowers and plants	34,704	18,505,881
Live-stock	134,748,135	1,654,135,912	Nursery products	137,459	10,279,135
Dairy produce	22,616,227	384,953,680	Taro	2,980	187,310
Tobacco	5,628,277	74,212,350	Coffee	14,123	290,850
Cotton	45,580,533	517,538,518	Miscellaneous	49,255,921	589,163,235

	Acres	Bushels	Value		Acres	Bushels	Value
Barley	4,470,196	119,634,877	$41,631,762	Oats	29,539,698	943,389,375	$217,098,584
Buckwheat	807,060	11,233,515	5,747,853	Rice	351,344	4,728,710	7,891,613
Corn	94,916,911	2,666,440,279	828,258,326	Rye	2,054,292	25,568,625	12,290,540
Kafir corn	266,513	5,169,113	1,367,040	Wheat	52,588,574	658,534,252	369,945,320

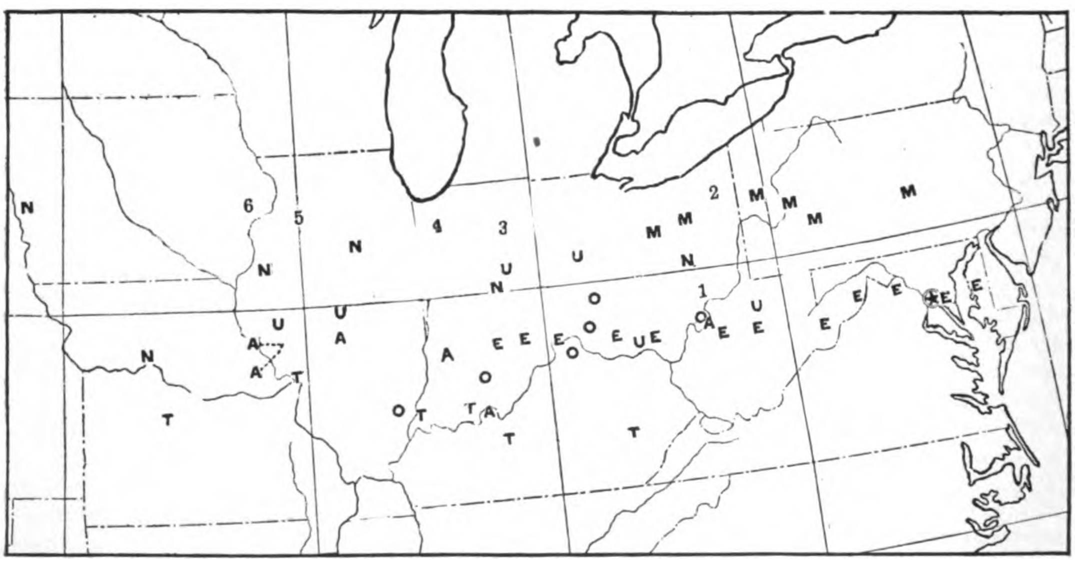


Fig. 9. Map showing the movement of centers of population from 1790 to 1900, and of centers of farms, agricultural products and manufactures from 1850 to 1900. The map shows the middle states from the seacoast to western Missouri and Iowa. O, number of farms; U, farm values; T, total areas in farms; 1, 2, 3, 4, 5, 6, oats production; A, corn production; N, wheat production; E, population; M, manufacture. The centers have moved steadily westward for each decade, except in the cases of oats and corn. The center of oat production moved northeastward between 1850 and 1860 (1-2); center of corn production moved slightly northeastward between 1890 and 1900. (Adapted from Census.)

The regions of greatest productiveness of corn, hay and forage, and cotton, as based on yields per square mile, are indicated in Figs. 11, 12 and 13. They are adapted from the Statistical Atlas of the Twelfth Census, 1900.

Live-stock.

The live-stock interest has shifted to the westward within the past generation. This does not signify, however, that the middle and western regions are naturally best adapted to live-stock or that

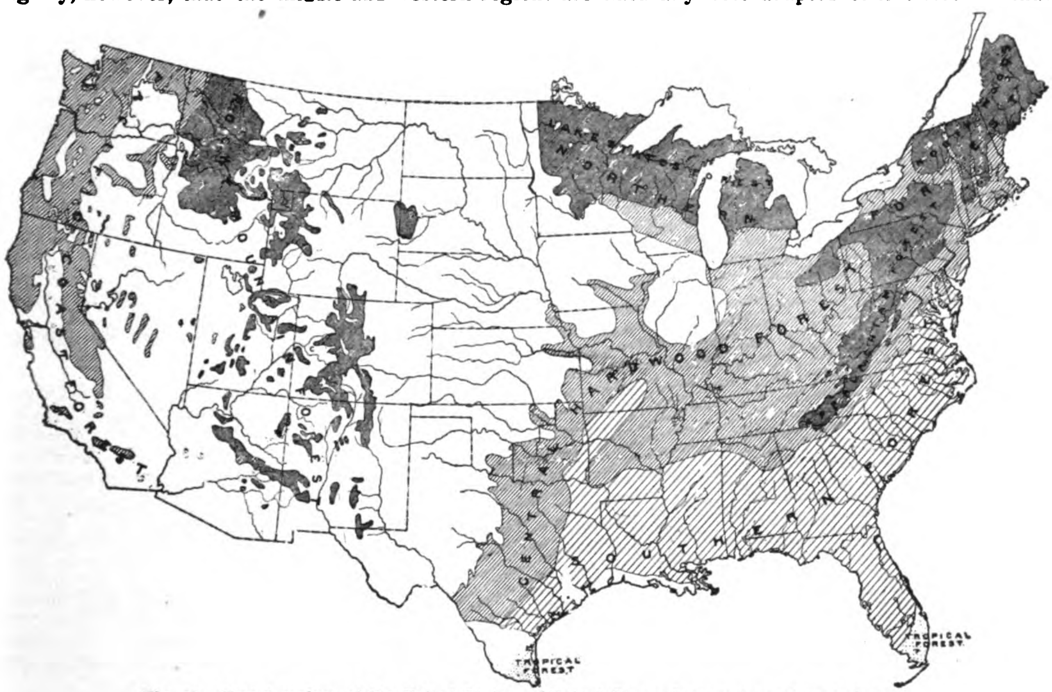


Fig. 10. Forest regions of the United States. (United States Department of Agriculture.)

the center of the industry is to persist there. It is rather the result of cheap land or public range, and also to the proximity of the corn-belt. The northeastern states and provinces, and the elevated lands of the Appalachian region to the southward, are better grazing lands so far as natural production of grass and abundance of water are concerned. With the developing of stall-feeding, the concentrated foods have come to be of unaccustomed importance. The corn products, producing some of these foods, are more cheaply grown in the mid-continental region, and eastern farmers have come to rely on them from this source. With the development of live-stock-raising in the corn-belt, however, more of these products will be used where they are grown. Stock-growing will develop more rapidly than corn-growing, for it is adaptable to a much wider area. Moreover, some of the corn is now shipped west to supply animals that are fed on the ranges instead of being shipped east to be put in condition. These facts will tend to increase the price of corn to the eastern farmer. With his excellent and abundant pasturage and hay, and ability to grow annual forage crops, the eastern man must now begin to produce his own concentrates or products that may take the place of them. The eastern states produce relatively over-heavily of hay and forage, and some of the central states over-heavily of concentrates. According to the Twelfth Census, the hay and forage crops of New York, for example, constituted nearly two-fifths of the value of all crops in the state, not including pasture, and more than one-eighth of the value of all the hay and forage crops in the United States. New York produces about one and three-fourths tons of hay per animal unit (approximately 1,000 pounds live weight of animal); Illinois produces three-fourths of a ton. New York produces about 800 pounds of grain concentrates per animal unit; Illinois produces 4,800 pounds.

There are a number of ways in which these new feeding demands may be met; some of them are as follows: by raising alfalfa, which is now extending rapidly eastward; by the more general growing of other and special forage crops; by means of root-crops; by the breeding of races of corn, clover and other crops that will be specially adapted to the East and the South.

The value of live animals sold in the United States in the Census report of 1900 was $722,913,114. The value of live-stock on farms, as reported by the same Census, was as follows:

1900	$3,078,050,041	1870	$1,525,276,457
1890	2,308,767,573	1860	1,089,329,915
1880	1,576,884,707	1850	544,180,516

Dairy industry.

The great growth of cities has been the reason of the developing of a new and more effective kind of dairying. Trains carrying only milk are now run to the large cities, often from very long distances. Dairy manufacture has come to be a prominent part of the instruction in agricultural colleges. Laws designed to protect and encourage the dairy business have been enacted. The coöperative creamery system, the butter factories and skimming stations, have greatly stimulated the business, and they are likely to set on foot new social movements. The production of butter and cheese reported by the Twelfth Census of the United States was as follows:

	Dairy Butter (made on farms)	Creamery Butter (made in creameries and butter factories)	Factory Cheese
Pounds made	1,071,745,127	420,126,546	281,972,324
Pounds sold	518,139,026		
Receipts	$86,606,446	$84,079,754	

The total production of cheese in 1899 from farms and factories amounted to 298,344,654 pounds.

The development of the dairy industry has been conditioned chiefly on three factors aside from the breeding of the animals themselves: the rise of markets; good natural pasturage; the perfecting of the silo, whereby the winter production of milk is increased. New kinds of buildings are now demanded, and these may be expected to modify profoundly many of the inherited ideas of farming. Dairying has not yet developed extensively in the South; although all live-stock industries are now receiving new attention there and will greatly increase.

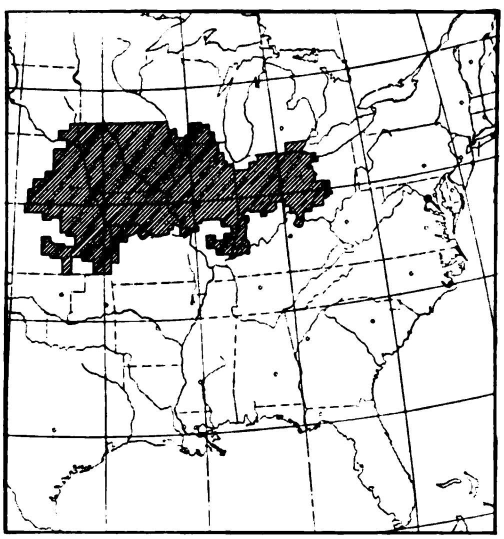


Fig. 11. Continuous section showing highest production of corn per square mile (3,200 bushels and above).

As reported by the Twelfth Census, 1900, three states have more than a million dairy cows:—New York, 1,501,608; Iowa, 1,423,648; Illinois, 1,007,664. In yield of milk, two states produce more than one-half billion gallons: New York, 772,799,352; Iowa, 535,872,240. In farm value of dairy produce, six states exceed twenty-five millions of dollars: New York, $55,474,155; Pennsylvania, $35,860,110; Illinois, $29,638,619; Iowa, $27,516,870; Wisconsin, $26,779,721; Ohio, $25,383,627. In number of farms deriving the chief source of income in 1899 from dairy produce, there are three states standing above twenty-five thousand: New York, 67,457 farms; Pennsylvania, 32,600; Wisconsin, 25,246. In the above categories, only three states south of the Ohio river are included in a list of the first ten, and these three—Missouri, Arkansas, Texas—stand at or near the foot of the lists, if included at all. The only marked exception is in the category of number of dairy cows, when Texas stands sixth.

Horticultural interests.

Fruit-growing has now escaped the small orchard that formed one of the subdivisions of a farm, and has come to be a farm business by itself. The most marked departure in very recent years has been the extension of the business on a large scale into Georgia, Texas and other southern states. We are no longer bound so closely to "fruit belts" as we were in the past. Systems of transportation, storage, refrigeration and marketing have been worked out; and the manufacture of fruit products has grown to large proportions. We shall probably see a large extension of some kinds of fruit-growing to the remoter cheap lands.

Some of the statistics of fruit products in the United States for the years 1899 and 1889 are given below:

Fruit	1899	1889	Fruit	1899	1889
Apples—bushels	175,397,626	143,105,689	Plums and prunes—bus.	8,764,032	2,554,392
Peaches and nectarines—bushels	15,433,623	36,367,747	Cherries—bushels	2,873,499	1,476,719
Pears—bushels	6,625,417	3,064,375	Apricots—bushels	2,642,128	1,001,482
			Grapes—pounds	1,301,013,407	1,145,315,160

Other horticultural industries are also escaping the old conventional forms of dependent or accessory avocations and are becoming independent occupations, practiced on a large scale. This is true even of glass-house industries, which are now conducted on a basis comparable with that of high-class field farming.

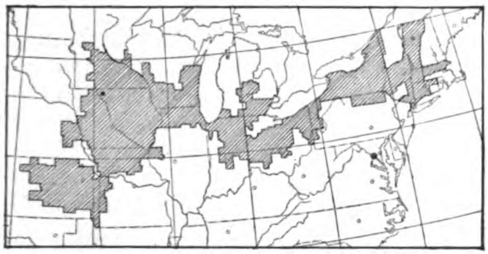


Fig. 12. Areas of highest productiveness of hay and forage per square mile (100 tons and above).

Exports.

The agricultural exports of the United States have about trebled in twenty-five years. While this is a measure of the excess of production over consumption and is a mark of national prosperity, it may or may not represent permanent increased efficiency in farming. It may be expressive of extent of land brought under cultivation. The following figures show the total values of exports of the leading products of domestic agriculture for a series of years, as given in the Report on Commerce and Navigation of the United States, 1904:

Year	Animals total	Provisions total	Total of all
1868	$432,566	$31,078,598	$276,254,779
1870	724,933	30,992,305	352,096,215
1878	4,497,576	124,845,137	515,955,203
1880	14,657,931	132,488,201	663,097,979
1888	12,051,085	93,058,080	477,253,696
1890	32,413,250	136,264,506	596,052,031
1893	26,555,984	138,401,591	576,933,573
1898	$39,151,873	$167,340,960	$793,003,747
1899	31,597,629	175,508,608	716,137,928
1900	31,763,443	184,453,055	750,215,684
1901	39,738,445	196,959,637	853,622,618
1902	31,930,602	199,861,378	762,682,139
1903	30,957,719	179,839,714	783,771,040

"Animals" includes cattle, sheep, hogs. "Provisions" includes bacon and hams, pork, lard, beef products, all other meat products, dairy products. The total includes also cotton (raw), breadstuffs, tobacco (unmanufactured).

Education.

Every state and territory in the Union has an institution in which agricultural education is provided for at public expense. The greater part of these institutions are founded on the federal Land Grant Act of 1862. Every state and territory also has an agricultural experiment station established on federal funds. Each of the states and territories receives $15,000 annually from the act of 1887, known as the Hatch Act; and additional funds, which will shortly duplicate these, are now accruing from the Adams Act of 1906. Two of the states (New York and Connecticut) have two separately organized experiment stations, one maintained by state funds; and many of the states supplement the federal funds. The location of these educational and experiment institutions is given with the descriptions of the various states on subsequent pages.

The federal government maintains a Department of Agriculture, the Secretary being a member of the President's Cabinet. This Department received appropriations of considerably more than six million dollars in 1905. It has a staff of more than five thousand persons, about half of whom are scientists and scientific assistants. Many of the states maintain efficient departments of agriculture, engaged in educational, inspectional, police and regulatory work.

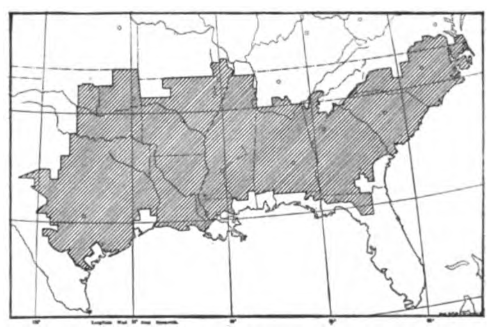


Fig. 13. The main cotton-producing region of the United States. (Twelfth Census.)

There are a few special schools engaged chiefly in secondary agricultural educational work, some of them on private foundations and others maintained by public funds. The number of such schools in the

United States that are now well established and effective probably does not much exceed a dozen. The public schools are interesting themselves in agricultural education, and agricultural knowledge is being shaped into teaching form; but no consistent method of secondary instruction in agriculture has yet been developed. It is to be expected that within ten years the experiment of teaching these subjects will have been well tried and some definite experience put into systematic form. There is everywhere a radical change in the philosophy of teaching, some of it characterized by the term nature-study, whereby the child is educated in terms of his own experience; and this is preparing the way for profound modifications in the schools.

The rise of agricultural sentiment.

Agriculture was once the dominant industry. For fifty years it has been overshadowed by the great growth of manufacture and merchandizing and the consequent rise of cities. The movement has been centripetal. A marked centrifugal movement is now well set in: it has almost become a fashion to own a farm. Whatever the extent and duration of this outward movement may be, it will have a permanent effect on public sentiment. The most hopeful change, however, is the pronounced rise in agricultural sentiment among the farmers themselves. Appropriations of public funds for agricultural purposes are no longer stinted in amount or narrow in policy. A liberal and general public appreciation of rural affairs has again arisen. We may expect endowments to be given for agricultural institutions as in the past they have been given to other objects.

It is not to be expected or hoped that the cityward movement will cease, but only that a sane selective process may arise, whereby it will be possible and popular for a person to live from the land. The cityward movement is world-wide. According to William Z. Ripley, in "The Races of Europe," "the impelling forces are reducible mainly to economic and social factors. Most powerful of these movements of population to-day is the constant trend from the rural districts to the city. Its origin is perfectly apparent. Economically it is induced by the advantages of coöperation in labor; perhaps it would be nearer the truth to say, by the necessity of aggregation imposed by nineteenth-century industrialism. This economic incentive to migration to the towns is strengthened by the social advantages of urban life, the attractions of the crowd; often potent enough in themselves, as we know, to hold people to the tenement despite the opportunity for advancement, expansion or superior comfort afforded elsewhere outside the city walls. The effect of these two combined motives, the economic plus the social, is to produce a steady drift of population toward the towns." The correctives of this tendency to move to town are of three sorts: a rise in the earning-power of the farm; betterment of social conditions in the country; a more sensitive personal appreciation of the desirable ends in life.

The rise of the agricultural industries will call for some radical readjustments of public policies. It is probable that we shall find ourselves agreeing that the country (as distinguished from the city) has certain rights that we have not thought of as belonging to it. There are also mutual obligations that are practically untouched. If it is true, for example, that farm produce carries necessary plant-food from the land (to cite one illustration out of many), then it follows that all mankind is concerned. The fertility is transported to the cities, and discharged into sewers. The fertility is not only wasted, but the waste pollutes the streams. Eventually these materials may need to be treated at public expense and perhaps returned to the land. One-half the population of the United States feeds the other half of non-producers. The producers would seem to have a right to the recovery of the fertility; or, at all events, the state would seem to be under obligations to consider the feasibility of recovering it in its own interest. The customary economic and social questions need to be re-studied from the agricultural or country-life point of view. Everything indicates the probability that the farmer is coming to his own; and he will now hold every advance that he attains.

The rise of agricultural sentiment is well reflected in the numbers of new books and periodicals. Some of these express only an extrinsic and reportorial interest in the subject, but they are nevertheless indicative of the time. There are many serious new books of permanent scientific value, representing the real progress and the genuine sentiment in agricultural affairs. These books and the agricultural periodicals are now indispensable to any farmer who expects to master his business. Most of the books deal with special topics. It is somewhat remarkable that there is so little cyclopedic treatment of agricultural subjects in this country. There is only one current American work of this nature, Wilcox and Smith's "Farmer's Cyclopedia of Agriculture," New York, 1905, a condensed, reliable and useful work in one volume.

AGRICULTURE IN CANADA

By C. C. JAMES

The typical Canadian farmer has no existence. There are Canadian farmers of several types, varying so widely in their farm-holdings, their methods of farming, and their results that a stranger would scarcely believe them to belong to one country. The maritime farmer, with his diked meadows reclaimed from the salt tidal waters of the Bay of Funday or Gulf of St. Lawrence, is one type; the French Canadian habitant of Quebec, often farming in the quaint methods of two centuries ago, is another type, distinct and interesting; the Ontario farmer, with his up-to-date methods and having the advantage of modern improvements in machinery, and methods of transportation, is a third type; the prairie farmer of Manitoba and the Northwest, full of enthusiasm and activity, who, within a year, turns the virgin prairie into a golden wheat field, is still another type. There are types intermediate between these, combining the peculiarities of two or more. Other types are rapidly being added, as from the four corners of the earth there come streaming into the great Northwest the tens of thousands of settlers from so many lands and with so many different inclinations. What the future of the agriculture of the Dominion will be, is a difficult question to answer, but it is safe to predict that probably for centuries to come agriculture will be what it has been almost from the first, the most important industry of Canada.

Capital invested in agriculture and manufacture.

At present, owing to the rapid expansion in the three prairie provinces, Manitoba, Alberta and Saskatchewan, it is impossible to keep figures up to date. The only statistics for all of Canada are those of the Census Year 1901, some of which must necessarily represent 1900. From that report is compiled the following table. In this table "farms" include holdings of five acres and over; "lots" include holdings under five acres:

	Farms	Lots	Totals
Number of occupiers	471,833	72,855	544,688
Land occupied—acres	63,334,815	87,523	63,422,338
Land improved—acres	30,083,921	82,112	30,166,033
Land in field crops	19,725,016	38,724	19,763,740
Value of lands	$1,004,923,792	$2,530,566	$1,007,454,358
Value of buildings	393,958,579	1,856,566	395,815,145
Value of implements and machinery	107,630,565	1,034,937	108,665,502
Value of live-stock	254,973,244	20,194,383	275,167,627
Total capital investment	1,761,486,180	25,616,452	1,787,102,632
Value of products (1900)	353,988,408	9,137,976	363,126,384

If a comparison is desired with any other country, it may be stated here that the total population of Canada in 1901 was 5,371,315.

The effect of expansion in Canadian agriculture is well shown in the production of the farms of Ontario. From the records of the Ontario Department of Agriculture, the following figures are taken:

FARM VALUES.

	Land	Buildings and implements	Live-stock	Total
1897	$554,054,552	$257,389,257	$93,649,804	$905,093,613
1898	556,246,569	263,031,628	103,744,223	923,022,420
1899	563,271,777	268,435,138	115,806,445	947,513,360
1900	574,727,610	276,812,500	123,274,821	974,814,931
1901	585,354,294	286,472,741	129,496,261	1,001,323,296
1902	604,860,063	299,489,455	140,544,814	1,044,894,332
1903	620,869,475	311,625,343	154,327,267	1,086,822,085
1904	640,544,541	323,987,694	163,383,103	1,127,915,338
1905	649,201,364	333,014,060	172,438,360	1,154,654,284

Comparisons are frequently made with other industries, and it is a common desire on the part of students to compare or contrast the agriculture of a country with its manufactures. For those who are so inclined, the following statistics of the manufacturing industries of Canada are appended, for the same Census Year:

MANUFACTURES OF CANADA, 1901.

Capital in real estate	$96,644,827	Total capital	$446,916,487
Capital in machinery	112,733,811	Value of raw materials	266,527,858
Working capital	237,537,849	Value of products	481,053,375

Those who compare these two great industries should avoid the mistake of making an unfair comparison by simply considering capital invested and value of finished products, for to a large extent the finished products of the farmer are the raw materials of the manufacturer. [Further interesting facts in this discussion may be found in the Census of Canada, 1901, Volume II; pp. xxxi, xxxii.]

The leading crops.

The growing of grass and grain have been, of course, the first agricultural operations in all of the provinces. The following table gives the acreage and yields of the three principal grain crops, wheat, oats, and barley, for the Census Year 1901:

	Wheat		Oats		Barley	
	Acres	Bushels	Acres	Bushels	Acres	Bushels
Ontario	1,487,633	28,418,907	2,707,357	88,138,974	586,010	16,087,862
Manitoba	1,965,200	18,353,013	573,858	10,592,660	139,672	2,666,803
Quebec	139,826	1,968,203	1,350,031	33,536,677	104,135	2,535,597
Nova Scotia	16,334	248,476	91,087	2,347,598	7,710	181,085
New Brunswick	26,990	381,699	186,932	4,816,173	4,581	99,050
Pr. Ed. Island	42,318	738,679	164,472	4,561,097	4,563	105,625
British Columbia	15,967	359,419	34,366	1,442,566	2,232	73,790
N. W. Territories	530,274	5,103,972	259,552	6,061,662	22,897	474,554

It should be noted that 1900 was an "off year" in Manitoba crops.

The only provinces collecting and publishing annual statistics are Ontario, Manitoba, and the Northwest Territories (in 1905, organized into the two provinces, Alberta and Saskatchewan). As indicating the changes taking place and bringing the figures more up to date, the provincial statistics are given:

	Wheat		Oats		Barley	
	Acres	Bushels	Acres	Bushels	Acres	Bushels
Ontario (1904)	833,485	12,631,726	2,654,936	102,173,443	772,434	24,567,825
Manitoba (1904)	2,412,235	39,162,458	943,574	36,289,979	361,004	11,177,970
N. W. Territories (1904)	965,549	16,875,537	523,634	16,332,551	86,154	2,205,434

The following is the full statement of wheat production in Canada for 1905:

		Acres	Bushels
Ontario	Fall	796,213	17,933,961
	Spring	190,116	3,582,627
Manitoba	Spring	2,643,588	55,761,417
Saskatchewan	Spring	1,130,084	26,107,286
Alberta	Spring	75,353	1,617,505
	Fall	32,174	689,019
Total		4,867,528	105,691,815

It wlll be seen from the above statements that the grain crops of Canada are grown mainly in Ontario, Manitoba, and the two new provinces of Alberta and Saskatchewan.

In Ontario, the country lying east of Toronto produces mainly spring-wheat, while that west of Toronto produces fall-wheat. All the wheat of Manitoba is spring-wheat. Most of that of the two new provinces is spring-wheat, but in southern Alberta a large area hitherto unknown as a grain-producing area, is now producing fall-wheat. The possibilities of Manitoba for wheat production are pretty well established; those of the two new provinces are the subject of much controversy. It is admitted that very extensive areas will be found available for producing the finest wheat of the world, but just how many million acres is a matter that time alone can determine.

Oats has been the great grain crop of Canada. Thus the Census of 1901 reports 5,367,655 acres producing 151,497,407 bushels, as compared with 4,224,542 acres of wheat producing 55,572,368 bushels. Ontario produces more than half the oat crop of Canada. While wheat-growing has of late steadily declined in Ontario, oat production has steadily increased. The crop is grown largely for stock-feeding, but the great increase in the production of breakfast foods has created an increased demand for this grain.

Three-fourths of the barley of Canada is grown in Ontario. Prior to 1890 large quantities were produced for export to the United States for malting purposes. The McKinley tariff closed the door and the barley crop dwindled to small proportions. Of recent years, however, the acreage has grown to its former size, and now this grain is extensively produced for feeding stock, for the production of bacon, beef and milk.

About ninety per cent of the peas of Canada is produced in Ontario, and mainly in western Ontario. The increase of the pea-weevil, of recent years, has caused a diminution in the area.

The great corn-fields of the central United States are unknown to Canada; yet nearly every farmer of Ontario grows some corn. In Essex and Kent counties of Ontario, large quantities of grain are grown for feeding and for distilleries, but the most common practice is to grow the grain to a condition approaching maturity and to preserve it in silos.

The student who desires to know more about the other crops of Canada is referred to Volume II of the Census of Canada for 1901, and also to the reports of the Departments of Agriculture for the different provinces. As already stated, statistics as to acreage and yields of the crops are published by the Departments for Ontario (Toronto), Manitoba (Winnipeg), Saskatchewan (Regina) and Alberta (Edmonton). The Yearbook of Canada, published annually by the Canadian Department of Agriculture (Ottawa), compiles these separate reports in a volume very valuable for reference.

Live-stock.

A marked improvement in Canadian agriculture has followed as attention has been directed to the breeding and feeding of live-stock. The early French settlers of Quebec naturally introduced breeds of cattle and horses from France, and, as a consequence, in that province are found the hardy French Canadian horses of comparatively small size, generally called ponies, and a type of cattle akin to the dairy breeds of the Channel islands and the northern provinces of France. The large influx of British settlers to Upper Canada (Ontario), beginning after the close of the Napoleonic wars, gave the first impulse to the introduction of the pure-bred strains of England and Scotland. Ontario farming has been developed largely through the coming in of British settlers, who are naturally fond of live-stock. The province is well watered by rivers and streams that are frequent and swift-flowing. The geographic conformation is such as to give an abundance of clear water. The natural pasturage is abundant; the climate is stimulating. Nature and man have here united in favorable conditions for the breeding and care of stock. As a consequence, this province has become the great breeding-ground for pure-bred stock, horses, cattle, sheep and swine.

In horses, the Clyde and Shire take the lead, though of late years attention has been directed to the Hackney.

In cattle, the Shorthorn is more widely distributed than any other. In the eastern part of the province the Ayrshire fills a large place in dairying. Of late, Holstein blood is rapidly finding its way into the herds. The Devon ox of early days has disappeared in the march of progress. There have been, and still are, some Jersey herds of continental reputation. The Hereford is almost unknown. There are a few good breeding herds of Galloways and Aberdeen-Angus.

In sheep, the Shropshires are as widely distributed as are the Shorthorns among cattle. There are also breeders of Southdowns, Leicesters, Cotswold, Lincoln and Dorsets; the Merino has about disappeared.

In swine, the Yorkshire, Berkshire and Tamworth find favor in the order named. The heavy pork-producing breeds have about disappeared.

From Ontario thousands of farmers and their sons have gone to Manitoba and the Northwest to start farming life anew. As they have become established on the prairies they have begun the developing of herds and flocks based on importations from the older provinces.

The main features of the Canadian live-stock industry are the following: Ontario has become the greatest breeding center for a great variety of breeds in all Canada; in fact, taking all the breeds into consideration, it is probably the greatest breeding center of the continent. The pure-bred stock of Ontario is valued at $5,000,000; that of all Canada, $8,000,000. Excellent breeds are being established in other provinces, especially in Manitoba. Ranching is practiced mainly in the province of Alberta, though the increase of wheat-farming is in many cases causing a narrowing of the grazing country.

The growth of the live-stock industry of Ontario gives the key to the prosperity of that province. The following figures for Ontario are worth examining:

	Value of live-stock on Ontario farms	Value of stock sold		Value of live-stock on Ontario farms	Value of stock sold
1897	$93,649,804	$29,753,509	1901	$129,496.261	$46,592,103
1898	103,744,223	34,450,583	1902	140,544,814	53,083,396
1899	115,806,445	38,457,018	1903	154,327,267	59,330,931
1900	123,274,821	41,642,617	1904	163,383,103	60.095,412

The greatest development has taken place in the last eight or ten years in the production of hogs for bacon and hams by the Ontario farmer. The swine sales in 1897 amounted to $10,080,812; by

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steady yearly increase they became $22.665,164 in 1904. The ham and bacon production of other provinces, also, is increasing. The total exports of all Canada for 1897 amounted to $5,844,000, and in 1904, to $13,022,000.

Dairy industry.

The forming of coöperative cheese factories in New York state, fifty years ago, was followed by the farmers of Ontario and those of Quebec living near the New York and Vermont frontiers. For forty years there has been steady expansion until now the eastern townships of Quebec and large areas of Ontario are devoted mainly to the production of butter and cheese. Quebec butter and Ontario cheese have established a reputation for high quality. Following are the products of 1901:

	Factory cheese	Creamery butter	Dairy butter
Ontario	$13,441,000	$1,528,000	$11,076,000
Quebec	7,958,000	4,917,000	3,671,000
Other provinces	822,000	796,000	6,322,000
Canada	$22,221,000	$7,241,000	$21,069,000

The dairy industry has received especial assistance by the various departments of agriculture. New Brunswick has a dairy school at Sussex; Quebec one at St. Hyacinthe; Manitoba, one in Winnipeg; and Ontario has three,—at Guelph, Kingston, and Strathroy. The Dominion Department has an efficient dairy branch looking after transportation and markets and instruction in the new provinces. In the year 1905 the Ontario Department of Agriculture had thirty-four instructors working under two chief instructors. The steady improvement in the quality of butter and cheese and the rapid increase in the output of the factories and creameries is the result of a comprehensive and thorough system of organization in which government departments, dairy schools, instructors, makers and patrons heartily coöperate. Canada owes much of its expansion in wealth in the past ten years to the beef steer, the bacon hog, and the dairy cow.

The following statement of the production of beef, bacon and cheese in Ontario in the past few years shows how Ontario agriculture has been growing through the extension of the live-stock industry:

	Beef	Bacon	Cheese	Totals
1897	$13,350,223	$10,080,812	$11,719,468	$35,150,503
1898	16,121,559	11,852,535	10,252,240	38,226,334
1899	17,303,426	14,157,394	12,120,887	43,581,707
1900	18,017,989	15,800,799	13,023,025	46,841,813
1901	20,286,963	17,548,490	12,269,073	50,104,526
1902	23,340,908	20,154,190	14,792,924	58,288,022
1903	25,867,963	22,532,862	17,203,233	65,604,058
1904	26,342,872	22,665,164	12,908,118	61,916,154

The drop in the value of cheese in 1904 was owing to the low market price, not to decrease in output. The largest yield in the history of cheese-making in Ontario was in 1903, when 165,306,573 pounds was the output; 1904 came next in order with 154,879,438 pounds, and 1902 third, with 146,805,776 pounds.

Horticultural interests.

Fruit-growing in Canada flourishes in the extreme eastern and western provinces, and also in the central. Brief reference may be made to the industry, taking the provinces in order:

Nova Scotia agriculture is noted particularly for two products, potatoes and apples. Some of the finest and most productive apple orchards of Canada are to be found along the Annapolis valley. From early Acadian days, the fruit trees have flourished in this beautiful sheltered valley. Gradually the orchards have extended to adjacent counties and to other valleys. The Gravenstein is the apple that is grown here to greatest perfection.

In New Brunswick, apple-growing for commercial purposes is becoming an important factor of agriculture in recent years. The farmers of this province are beginning to take a share in the apple production of the maritime provinces.

In Quebec, apple-growing is mainly confined to the Island of Montreal and the counties south of the St. Lawrence, adjacent to Lake Champlain. Here is the original home of the Fameuse apple. For eighty years and more the Island of Montreal has been noted for its muskmelons. The Outremont melon of Montreal is to-day one of the most expensive melons to be found in the high-priced hotels and restaurants of New York, Boston and other cities.

In Ontario, with its variety of soil and climate, is found the greatest variety in fruit production. In studying the fruit-growing possibilities of Ontario, an acquaintance with its geographical situation is necessary. (See Fig. 27.) The old settled part is thrust down into the midst of the United States and lies in the great agricultural belt of the continent. Add to this a rolling surface giving sheltered valleys, very extensive shore-lines, and the modifying climatic influence of the Great Lakes, and there is explanation of the fact that the finest peaches and the hardiest apples are grown in fairly close proximity to each other. Apples grow everywhere, although the sections adjacent to the Great Lakes are the most productive. Pears for export are produced of best quality near the head of Lake Ontario. Plums are grown in greatest quantity on the south shore of Georgian bay and in the Niagara peninsula. Grapes, for commercial purposes, are found in the Niagara District and in the southwest in Essex county. Wine-making is practiced extensively in these sections. Peaches are grown in largest quantity in Lincoln county adjacent to Niagara, and in Essex county, along Lake Erie. The strip of ground lying along the western end of Lake Ontario is protected by a high bluff, the continuation of the Niagara Falls escarpment. This strip, varying in width, has been the most productive and, consequently, has the highest priced fruit land in Ontario. Small-fruits are widely distributed. The canning industry is expanding rapidly. For many years the Ontario fruit-grower and the canners sent their surplus product to England. The recent increase of population in Manitoba and the Northwest has now demanded a part of this trade, and, at present there are signs of a rapidly increasing trade in that direction.

Manitoba and the Northwest (Alberta and Saskatchewan) will not for many years, if ever, produce fruit to supply their home markets.

In British Columbia, the conditions closely resemble those in Oregon and Washington. The rich soil of the valleys and the mild Pacific coast climate give fruit-growing great advantages. The trees mature early and the fruit is large sized and well colored. The orchards are comparatively young, but already British Columbia apples and plums are finding their way to the markets of the prairies and the prospects are bright.

The great bulk of the fruit of Canada, however, is produced in Ontario, as the following table from the Census of 1901 will show:

	Ontario	Other provinces	All Canada
Apples—bushels	13,631,264	4,994,922	18,626,186
Peaches—bushels	539,482	5,933	545,415
Pears—bushels	480,759	51,098	531,857
Plums—bushels	337,108	220,767	557,875
Cherries—bushels	132,177	204,574	336,751
Grapes—pounds	16,232,020	5,475,271	21,707,291

Apples constitute the main fruit exports of Canada, the quantity varying from one to two million barrels a year.

Every province has its fruit-growers' society, the reports of which may be consulted for further information. There is also a Fruit Branch of the Dominion Department of Agriculture (Ottawa), which is concerned with packing, shipping and marketing fruit.

Agricultural exports.

The following table of the exports of Canadian agricultural products shows the rapid expansion that has taken place, especially in recent years. The Confederation of the Provinces was formed in 1867, and the figures, therefore, begin with 1868:

	Animals and their products	Field products	Total		Animals and their products	Field products	Total
1868	$6,470,332	$12,871,055	$19,341,387	1900	$54,341,841	$27,516,609	$81,858,450
1878	12,793,256	18,008,754	30,802,010	1901	53,849,480	24,781,486	78,630,966
1888	22,751,096	15,436,360	38,187,456	1902	57,364,331	37,152,688	94,517,019
1893	30,253,416	22,049,490	52,302,906	1903	67,419,044	44,624,321	112,043,365
1898	42,771,573	33,063,285	75,834,858	1904	61,664,159	37,138,875	98,803,034
1899	45,187,843	22,952,915	68,140,758	1905	60,956,875	29,331,608	90,288,483

The above figures for animals and their products differ from the Trade and Navigation Returns because they do not include furs. The years in each case end on June 30, the close of the Canadian fiscal year.

The following statement gives the exports of Canadian farm produce for 1905 in all cases in which the totals exceed one million dollars:

Cheese	$20,300,500	Wheat flour	$5,877,607
Wheat	12,386,743	Canned meats	3,538,976
Bacon	12,194,458	Apples	2,627,467
Cattle	11,338,431	Hay	1,261,210
Butter	5,930,379		

Government assistance.

Agriculture in Canada is well protected and assisted by the various governments. The federal government has a minister of agriculture, who presides over a department with many branches. Under his direction are five experimental farms: Central Experimental Farm at Ottawa; the Maritime Farm at Nappan, N. S.; the Manitoba Farm at Brandon; the Northwest Territory Farm at Indian Head; and the British Columbia Farm at Agassiz. The various branches of the department—Dairying, Live-Stock, Fruit, Poultry, Pure Seeds, and Markets—are concerned mainly with the questions of transportation and marketing.

Education is a function of provincial government. Prince Edward Island provides agricultural education and directs experimenting through the professor of agriculture of Prince of Wales College. Nova Scotia has recently opened an agricultural college at Truro in close coöperation with the Provincial Normal College. New Brunswick maintains a dairy school at Sussex. These three maritime provinces enjoy in common the advantages of the Dominion Experimental Farm at Nappan, Nova Scotia, the New Brunswick Dairy School at Sussex, and the agricultural college at Truro, where live-stock has become the most important feature.

Quebec has a dairy school at St. Hyacinthe, and gives grants to several agricultural schools that are conducted by religious orders. There are ten experimental fruit stations. The southwestern part of Quebec (that is, the English-speaking part) and the eastern part of Ontario will, in the near future, be benefited by the magnificent agricultural college now in formation on the western end of the Island of Montreal (St. Anne de Bellevue), erected and endowed through the liberality of Sir William Macdonald. The extent of this new institution may be understood when it is stated that it will be endowed by several millions of dollars.

Ontario has the most extensive system of government organizations. There is an agricultural college at Guelph, with its well-equipped allied Macdonald Institute for young women. There are three dairy schools,—at Guelph, Kingston and Strathroy. There are twelve experimental fruit stations. There are provincial organizations of all the different branches of agriculture. The Department of Agriculture at Toronto publishes the following reports in addition to bulletins and special reports: Ontario Agricultural College, Experimental Union, Dairy associations, Fruit-growers, Fruit Experiment Stations, Farmers' Institutes, Women's Institutes, Entomological Society, Live-stock associations, Bee-Keepers, agricultural societies, agricultural statistics.

Manitoba conducts a dairy school and has an agricultural college near Winnipeg. Classes were first organized November 7, 1906.

British Columbia has for some years maintained vigorous dairy and fruit-growers' branches, and exercises a close supervision over horticultural imports and exports.

The dominion and provincial departments combined expend in all about one and a half million dollars every year for the benefit of the agriculture of Canada.

LIFE-ZONES IN RELATION TO AGRICULTURE

By T. D. A. COCKERELL

Every one is aware that the same animals and plants are not found in all localities, and that all regions are not suited for the same crops. The presence of any particular kind of animal or plant in any particular place is due to or permitted by several different factors. In the first place, if it did not originate there, it must have had some means of traveling from the place where it did originate, and sufficient time must have elapsed for the journey. In the second place, if it is able to maintain itself in its present habitat, the surroundings must be sufficiently favorable, or it must be sufficiently well adapted to them.

In a broad way, these factors may be said to be chiefly historical and climatic. The agriculturist is concerned with the latter rather than with the former. The southern extremity of Florida has a tropical climate, but it has not such a characteristically tropical fauna and flora as the island of Cuba. From the standpoint of the naturalist, it is to be classed with the adjacent and contiguous land to the north, rather than with the West Indies. Nevertheless, such West Indian types as have reached it do well there, and man is able to raise such crops as the climate allows, without being in the least disturbed by the fact that the sea has been a barrier to the larger part of the native West Indian fauna and flora. In other words, the agriculturist is concerned with what now is, rather than with what has been, and with existing conditions of soil and climate, not with "natural barriers," which are no barriers to him.

In the Rocky mountains, there are numerous kinds of oaks, which abound in New Mexico, and grow north to central Colorado, where they abruptly stop. From the altitudes at which they are found in New Mexico and southern Colorado, there appears to be no climatic reason why they should not range much farther north. It appears probable that they were driven south during the glacial period and have

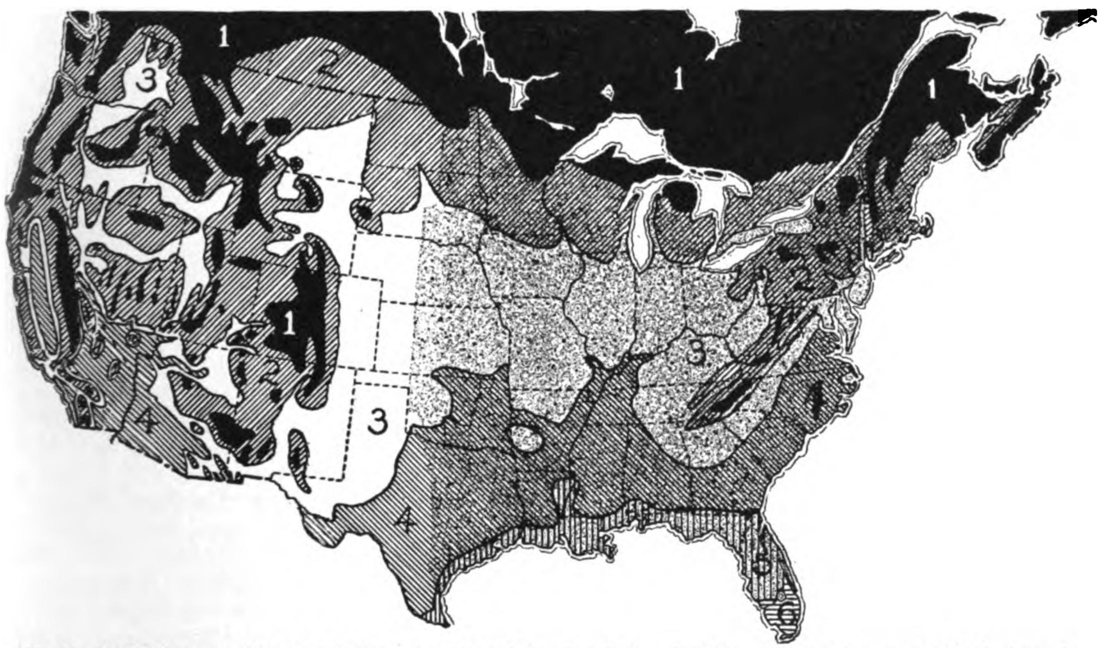


Fig. 14. Main Life-zones of the United States and adjacent Canada.—1, Boreal; 2, Transition; 3, Upper and Middle Austral; 4, Lower Austral; 5, Gulf strip of Lower Austral; 6, Tropical. The dotted parts of the Austral zones east of the great plains indicate the extent of the humid divisions of these zones, known respectively as the Alleghanian, Carolinian and Austro-riparian faunas. The undotted parts of the same zones are known as the Transition, Upper Sonoran and Lower Sonoran (adapted, with modifications, from C. Hart Merriam).

not yet recovered the lost territory, their fruit (the acorn) being heavy and not readily carried great distances, especially in the absence of rivers flowing north and south. This is very interesting to the naturalist, but such phenomena do not affect the agriculturist, who is able to take his seeds or plants wherever they will grow.

The present and past existence of "natural barriers" may even be favorable to man's operations. Thus the curious Australian tree, Casuarina, is grown from seed in the West Indies, and is practically free from insect enemies, because the numerous kinds which infest it where it is at home have never been able to cross the Pacific Ocean, or otherwise reach this side of the world. The same is true of the Eucalyptus trees in California.

In defining zoölogical and botanical regions, naturalists have taken the combined results of all factors, as exhibited in the existing faunas and floras, and, in consequence of this, the regions have not been found altogether applicable to agriculture. For example, the north of Africa is, zoölogically and botanically, strikingly different from southern Arizona. Nevertheless, the investigations of the Department of Agriculture have shown that it presents great climatic similarity to the Salt river valley and adjacent country, and the date-palm, native in the one, has been successfully introduced into the other.

This introduction will be followed by others, until the agricultural and horticultural products of the United States include all the valuable ones at present existing in climatically similar areas of the Old World.

Dr. C. H. Merriam, of the Department of Agriculture, having in view the economic side of the question, undertook, a number of years ago, to define the great Life-zones that cross the United States, as the result of climatic conditions. In this he was so successful that, in its main outlines, his work is everywhere accepted, and is used to throw light on very numerous and varied problems. It was found that there are two great areas, occupied by the boreal or northern, and the austral or southern types, respectively. There is also an intermediate territory, in which they mingle, and where they seem to struggle together for dominance. The spread of the boreal types southward is evidently prevented to a considerable extent by the competition of the austral ones, and vice versa; but more important factors seem to be those of temperature and moisture, exactly those that are so important in agriculture.

Life is continually adjusting itself to the physical environment. The processes of nature constitute, as it were, a great experiment, lasting for an indefinite period. Hence the plants and animals of any locality, to the eye of the discriminating observer, afford an accurate criterion of the climatic conditions, and consequently a reliable indication of agricultural possibilities. It is natural to ask, why attack the subject in such a roundabout way? Why not treat the records of the Weather Bureau as certain and satisfactory indications of climate, and leave the indigenous plants and animals out of account? The answer is, that the fauna and flora exhibit the work of nature's weather bureau, which has been in operation for centuries, instead of a few years; and further, that plants and animals may be found nearly everywhere, whereas weather stations are few and far between. Moreover, instrumental weather records do not give a complete account of climate, for some of the features of climate are quite unmeasurable and unrecordable in figures. It would be foolish for either the naturalist or the agriculturist to ignore the work of the meteorologist; but this work can be usefully supplemented, especially in mountainous regions, by observation of the native products. Correlations between plants or animals and climate, once recorded, can be used to determine the details of the climate of broken-up and varied regions where complete weather observations would be totally impossible.

In 1894, Dr. Merriam formulated a law, that the northward distribution of animals and plants in the northern hemisphere is determined by the sum of the effective temperatures (or the total quantity of heat) during the season of growth and reproduction. It is not sufficient that the organism should live: it must reach maturity and reproduce. Thus, for example, Indian corn is readily grown in England, but it is rarely able to mature, and there is no likelihood of its being a profitable crop in that country. This maturity depends on the long continuance of a suitable amount of heat, just as a man's maturity results, not from his last meal alone, but from a sufficient succession of them. Roughly, the "biological isotherms" have been mapped by adding together the numbers represented by the temperatures of the days concerned, until in each case the proper total was obtained. Commenting on this method, Professor C. H. T. Townsend (1895) observed that another factor must be considered, namely, the lowest temperatures during the winter season. Some organisms are not affected by low temperatures at this time, but others are; the coconut-palm, for example, cannot endure frost, while the date-palm can doubtless endure as much as anywhere goes with sufficiently high summer temperatures.

Professor Townsend further observed, however, that it is an error to base the conclusions as to distribution wholly on the temperature of the air, as shown by the ordinary thermometer. Different amounts of moisture, as well as the prevalence of winds, greatly affect the "sensible temperature," because of their influence on evaporation. If one pours a little alcohol or ether on the hand, the place at once feels cold, because the evaporating liquid takes up the heat. In the same way, the transpiration which all animals and plants show, giving off moisture into the air, must greatly affect their powers of resistance to extremes of temperature. It is related that on one occasion some persons walked into a large brick oven, with food cooking all around them, and escaped unscathed, to the wonder of onlookers. The explanation was that their rapid and profuse perspiration saved them. But since the rapidity of evaporation depends not merely on the temperature, but also on the amount of moisture already in the air, it is evident that high temperatures will be more oppressive to man and animals in damp climates than in dry ones. This is actually the case, and white men walk about without fatigue or danger in the arid southwest, in temperatures which would produce heat apoplexy in the moist tropics. The effect of wind is also important, and in the arid regions it frequently produces so much transpiration in cultivated plants that desiccation results, and hence windbreaks become of great value. The relation between the "actual" and "sensible" temperatures has been well described by Mr. Willis L. Moore, in a paper entitled "Some Climatic Features of the Arid Regions," published in 1896 by the United States Weather Bureau. In this work it is shown that the "sensible" temperature, obtained by the wet-bulb thermometer, may be many degrees below the air temperature, this difference in the arid regions during the summer months often amounting to 20° or 30° Fahr.

It is also evident that the relation between organisms and temperature is far from being a simple one. We are nct to assume, because two plants grow on the same isotherm, and mature at the same time, that they are equally affected by the available heat. The amount of leaf-surface exposed, the

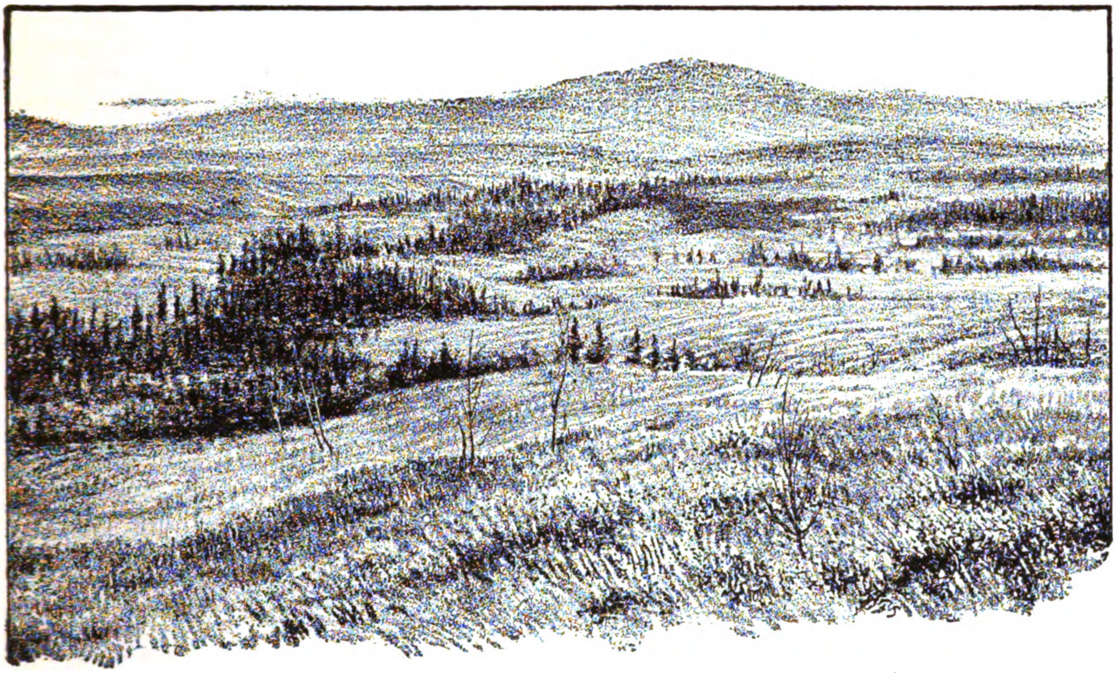


Fig. 15. Vegetation in the boreal zone, as it approaches the arctic sub-zone.—The tundra, Copper river valley, Alaska.

rapidity of transpiration, the situations occupied, and other factors are influential, and the general result must be explained in partly physical and partly physiological terms. The situation occupied is often so influential that, if one is ignorant of it, one may reach the most erroneous conclusions. Thus at Pecos, New Mexico, within an area of less than a square mile, without more than a hundred feet difference in altitude, the writer found plants characteristic of the arid austral zone, and others usually looked for in the boreal zones of the mountains. The former were growing on the rocky hillside, the latter under the shade of a dense grove of cottonwoods close by the Pecos river. Studying the matter on the spot, it seemed simple enough; but if the distribution records had been found plotted on a map, the most curious conclusions might have been reached. Similarly, at Minnehaha Falls on Pike's Peak, Colorado, the two sides of the deep cañon have quite different floras. The north side, exposed to the sun, has such plants as are found in the transition zone, while the south side, cold and damp, has a boreal flora. Just such conditions as these can be taken advantage of in agriculture, and it is no doubt an important part of the wisdom of farming, to choose suitable slopes and provide shade when necessary. So true is this in the arid west that, within the same immediate vicinity, one farm may be worth twice as much as another, at least for certain purposes. In Wet Mountain valley, Colorado, there is a small area, near a hill, where the currents of air meet in such a way that hail falls there more frequently than elsewhere, and this particular place may be white after a storm, in strong contrast with the rest of the valley. A more important kind of local influence is observed in the valleys of New Mexico and Arizona. The cold air, being heavier than that which is warm, flows like a stream of water to the bottom of the valley, and consequently the lower altitudes are actually colder than the higher ones. In Salt river valley, Arizona, for example, oranges are much less likely to be injured by cold at the sides of the valley than in its middle; and in the Mesilla valley a very moderate elevation may make the difference between a killing frost and a comparatively slight one. In the latter valley, if irrigation could be carried to a higher level, it is probable that the injury from spring frosts would be much reduced. These local phenomena seem to contradict the general rule that higher altitudes are colder, and yet they are real enough, and may not be ignored without loss.

In order accurately to map the life-zones all over the country, an immense amount of work would be necessary. The maps we possess at present are only approximately correct. This is true not only of the general maps, which treat the matter in the broadest way, but also of the more special ones, intended for particular purposes. Thus, for instance, a bulletin of the Division of Chemistry, Department of Agriculture (1899), contains a large map, showing the probable areas suited to beet-culture, between the isotherms of 69° and 71°. This map is based on the records of the Weather Bureau, and was supplied for the particular purpose in mind. The writer has had occasion to examine somewhat critically the New Mexico part. When this is compared with the larger detailed maps issued by the Weather Bureau, it is seen to be rough and general and not reliable for practical purposes. As a matter of fact, it does not indicate the actual areas suited to the beet, as proved by numerous experiments in growing this plant. Again, when we come to examine minutely even the large and detailed temperature maps, we find that they are based on the records of a few stations, which do not at all represent the various conditions existing in a mountainous country. This is not said in criticism of the Weather Bureau, or of any other bureau or of any person, but only to show the inadequacy of our knowledge; for to obtain really complete meteorological and other statistics would require an expenditure of money which it is not likely that Congress would ever sanction. Using the data obtained here and there, the Weather Bureau has to fall back on the work of the Topographical Survey, and assume that its contour lines fairly correspond in local areas with isotherms. But again, the work of the Topographical Survey, in many parts of the west, has had to be done with quite inadequate means, and therefore is frequently inexact as to details. So, taking one thing with another, it is quite impossible to furnish accurate detailed life-zone maps at present, except in a few regions which have been carefully gone over. The work of the Biological Survey, which, as explained above, is so necessary for the correction and amplification of data obtained in other ways, should be greatly extended. Its scope should include the details of the distribution of plants, both native and cultivated, and the Weather Bureau should be able so to coöperate as to bring out the necessary facts. In all these matters, an excellent beginning has been made, but it must be recognized that much more is to be done, and that it is useless to expect satisfactory results without the expenditure of much time and money; and the means will not be forthcoming until public sentiment rises to meet the needs.

The accompanying map, adapted from that of Dr. Merriam, indicates the life-zones according to present information, without any attempt, however, to go into great local detail. The zones may be further described as follows:

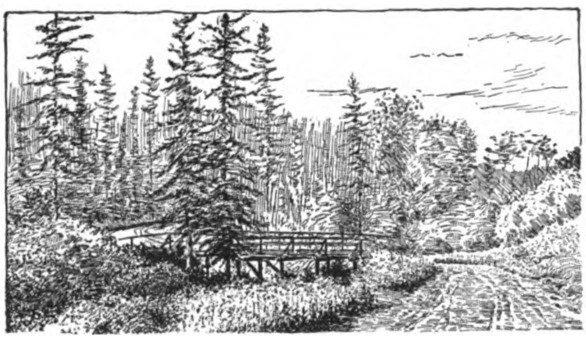


Fig. 16. Vegetation in northern Alberta, illustrating the Hudsonian sub-zone.

(*A*) *Boreal.*

The boreal zone may be divided into three sub-zones:

(*a*) *Arctic-alpine zone.*—In the arctic regions, beyond the limit of trees, and in our high mountains, above timber-line. The arctic and the alpine parts of it are not identical in their climatic features, the continuous light in summer of the far north being in strong contrast with the regular day and night of the mountain peaks that arise out of the temperate regions. In accordance with this, Gaston Bonnier has observed that arctic and alpine plants assumed to be of the same species differ essentially in structure from one another; and in recent years Rydberg, Wight and others have discriminated as new species plants of the higher Rockies, which were supposed to be identical with those of the extreme north. The Arctic-alpine zone is, of course, not adapted for agricultural purposes.

(*b*) *Hudsonian zone.*—So called from its prevalence in the vicinity of Hudson's Bay. It is the zone of "black timber" in the Rocky mountains, the great trans-continental zone of spruces and firs, occurring in comparatively small isolated areas in the eastern states, but in the west more extensive and important. It is not an agricultural zone in the ordinary sense, but, when we regard timber as a crop, it assumes a very high economic value, while in the arid west it is of prime importance as the recipient and conservator of the moisture which ultimately irrigates the varied crops of the plains. The farmer should as strongly resent the destruction of the Hudsonian zone forests, by indiscriminating axe or fire, as he would the destruction of his reservoirs or ditches.

(c) *Canadian zone.*—This is defined as follows by Dr. Merriam: "The Canadian zone comprises the southern part of the great transcontinental coniferous forests of Canada, the northern parts of Maine, New Hampshire and Michigan, a strip along the Pacific coast, reaching as far south, at least, as Cape Mendocino in California, and the greater part of the high mountains of the United States and Mexico. In the east it covers the Green mountains, Adirondacks and Catskills, and the higher mountains of Pennsylvania, West Virginia, Virginia, western North Carolina, and eastern Tennessee. In the mountains of the west it covers the lower slopes in the north and the higher slopes in the south. In the Rocky mountain region it appears to reach continuously from British Columbia to west-central Wyoming, and in the Cascade range from British Columbia to southern Oregon, with a narrow interruption along the Columbia river." It is a zone of varied and luxuriant vegetation, where the northern types reach a high state of development. It is usually thought of as purely boreal, but in the mountains of Colorado even its upper part is invaded by a not inconsiderable austral element, especially found in open and comparatively dry places. It is a zone of wild small-fruits, such as blackberries, raspberries and cranberries, and in many places it is found to be suitable for the cultivation of the potato, timothy grass, and some of the more hardy cereals.

Fig. 17. **Canadian sub-zone.—Vegetation in the pine woods of Michigan.**

(*B*) *Transition.*

This zone is, of all others, the most difficult to define, because it is the meeting-place of the boreal and austral elements, which mingle in varying proportions. It is, however, really more austral than boreal, and may justly be regarded as the first of the austral zones, going southward. It must be subdivided into three areas, as follows:

(*a*) *The Alleghanian area.*—This is the humid Transition of the country west of the hundredth meridian. It is especially prominent in Minnesota, Wisconsin, Michigan, New York, Pennsylvania, Ontario, New England and the Alleghany region. In this area the "chestnut, walnut, oaks and hickories of the south meet and overlap the beech, hemlock, and sugar-maple of the north" (Merriam). Wheat, oats, barley, rye and certain varieties of corn (King Philip, Longfellow, Pride of the North, and other flint varieties) are grown. The deciduous fruits are highly successful, and it is also a region of hops, potatoes and sugar-beets.

(*b*) *The Arid Transition area.*—For brevity and uniformity, this might be designated the Coloradian area. It occupies large parts of Colorado, Utah, New Mexico, Wyoming, Nevada, and the northwest, and is, for the most part, rather barren when not irrigated. It is characterized by the abundance of yellow pine and various species of artemisia, popularly called sage-brush. Under irrigation and cultivation it is most prolific, especially in the deciduous fruits, the sugar-beet, the potato, and various cereals, including corn. It is not suited for the wine-grape, but the native American grapes do well, and all sorts of small-fruits.

(c) *The Humid Northwestern area.*—This might be designated the Columbian area, from the Columbia river. It is very different from the Coloradian, being very humid, with more uniform temperatures and less sunshine. In places, the annual rainfall amounts to 100 inches. The forests are most luxuriant, and the whole country is full of life. Many deciduous fruits, as well as hops, potatoes and

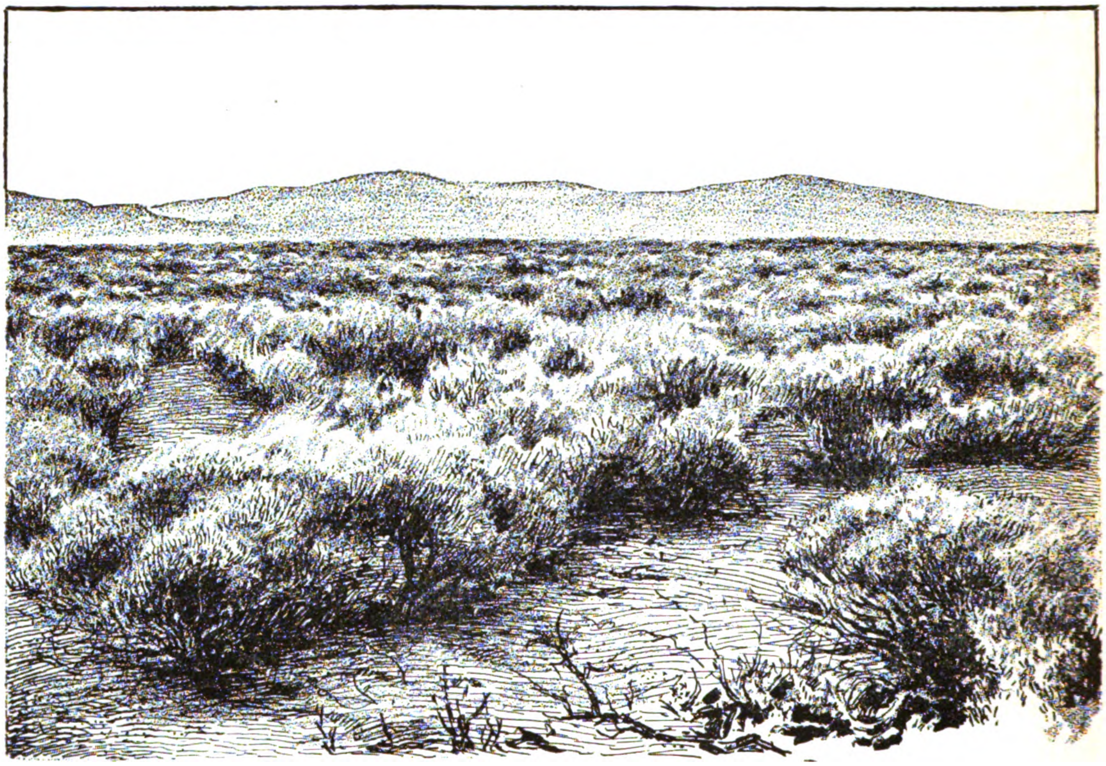


Fig. 18. Arid Transition area.—Sage-brush plains, Washington.

sweet corn, are grown. The region seems not to be well adapted to cereals, as in Dr. Merriam's list only one variety of wheat (Red Fife) is cited, and that is marked second-class, while of oats only two varieties are considered perfectly suitable.

(*C*) *Upper Austral.*

(1) East of the Hundredth Meridian.

(*a*) *The Carolinian area.*—This includes the whole of the Upper Austral of the relatively humid eastern states. It is found in eastern Nebraska and Kansas, Iowa, Missouri, Illinois, Indiana, Ohio, Kentucky, New Jersey, Delaware, Maryland. In it, the traveler from the north first meets with the sassafras, tulip tree, hackberry, persimmon. This, of course, is a region of prime agricultural importance. It is adapted to various kinds of wheat, oats, corn, barley, rye, apples, cherries, grapes, peaches, pears, plums, strawberries, flax, hemp, lima beans, sorghum, sugar-beet (though this is more characteristic, perhaps, of the Transition), tobacco and potatoes. The details of the distribution of these crops will be found discussed under the headings of the several states, and of the crops themselves.

(2) West of the Hundredth Meridian.

(*b*) *The Upper Sonoran area.*—The zone in the arid region corresponding to the last. It includes country which is nearly all open, with rather scanty vegetation of atriplex and other shrubby plants.

Cottonwoods (Populus) usually fringe the rivers. Under irrigation, this area is very prolific, and it is most curious in this and the Lower Sonoran of the arid west to see luxuriant orchards and fields, separated merely by a wire fence from a barren desert. In addition to most of the products named as flourishing in the Arid Transition, we find wine-grapes in abundance (though they have to be protected by banking in winter), as well as alfalfa (or lucerne), Kafir corn, sorghum, sweet-potato and tobacco.

(c) *The Middle Sonoran area.*—Characterized by the same crops as the Upper Sonoran, but with many of the plants (such as the larrea) and animals of the Lower Sonoran. So far as the native products go, it is in many ways a sort of Transition Sonoran, and Dr. Merriam, in all his maps, classes it as Lower Sonoran. It is subject to severe frosts in winter and spring, rendering it quite unsuited to the orange, olive and other characteristic fruits of the Lower Sonoran, so that to class it as such is misleading to the farmer or horticulturist. Mesilla valley, New Mexico, may be taken as typical of this area.

(*D*) *Lower Austral.*

(1) East of the Hundredth Meridian.

(a) *The Austro-riparian area.*—Dr. Merriam says: "The Austro-riparian area occupies the greater part of the South Atlantic and Gulf states. Beginning near the mouth of Chesapeake bay, it covers half or more than half of Virginia, North and South Carolina, Georgia, Florida, Alabama, the whole of Mississippi and Louisiana, eastern Texas, nearly all of Indian Territory, more than half of Arkansas, and parts of Oklahoma, southeastern Kansas, southern Missouri, southern Illinois, the extreme southwestern corner of Indiana, and the bottom-lands of western Kentucky and Tennessee." This is the zone of the cotton-plant, sugar-cane, rice, pecan and peanut, but, as defined above, it includes somewhat varied elements, and it is probable that further subdivision would conduce to clearness. It is, of course, a notable fruit zone, but it is principally distinguished from the Carolinian, agriculturally, by the production of cotton and cane-sugar. Its upper limit seems to coincide remarkably well with the upper limit of cotton cultivation, as shown by the report of the Census Bureau.

(b) *The Semi-tropical or Gulf strip.*—This reaches from Texas to southern Florida, and is subtropical in its climate. As defined by Dr. Merriam, it is a part of the Austro-riparian. It is the region of the palmetto and Cuban pine, and of the citrous fruits, though the last have suffered severely from frosts in the northern parts. It is, of course, especially the region of the sugar-cane.

(2) West of the Hundredth Meridian.

(c) *The Lower Sonoran area.*—"The Lower Sonoran area comprises the most arid deserts of North America, and is characterized by a fauna and flora of extreme interest. Among the commoner plants are the creosote bush, mesquites, acacias, cactuses, yuccas and agaves." At first sight, it appears wholly unsuited for agricultural purposes, but with irrigation a total transformation is wrought, and the apparently barren soil produces abundantly. Oranges, olives, almonds, peaches, pears and walnuts are among the principal fruits, though even in the warm Salt river valley of Arizona, typically Lower Sonoran, almonds have to be protected by "smudges" from the spring frosts. Alfalfa produces several crops a year, and sorghum is much grown. In this area, particularly southward, there are various native annual plants that flourish in the late winter and early spring, constituting a peculiar and interesting flora. At the same time, it is possible to raise various crops that are usually thought of as belonging to cooler regions, and for which the summers are much too hot and dry. The Chinamen, in particular, take advantage of this double climate to produce winter and spring vegetables in great quantity.

(*E*) *Tropical.*

The Tropical zone proper reaches the mainland of the United States only at the southern extremity of Florida. It includes, of course, the whole of Porto Rico, the Philippines and Guam, as well as the Hawaiian Islands. In the Hawaiian Islands and the Philippines are various high mountains, which should be differentiated from the purely tropical lowlands, and which will afford much material for interesting investigations. Whether American ingenuity will take advantage of these high lands for the production of crops not hitherto known there, as the British have done in certain of their colonies, remains to be seen, but it can hardly be doubted that such will be the case. The remarkably interesting results of the investigation of the Hawaiian and Philippine mountains by naturalists cannot be described in this place.

In the maps published by the Department of Agriculture, Dr. Merriam makes the Tropical zone enter southern Texas, and run a considerable distance up the Colorado river, into Arizona and California.

This was strongly objected to by Professor C. H. T. Townsend, who defined the Tropical zone as the region without frost. The valley of the Colorado river not only suffers from frosts, but is actually less suited for semi-tropical products than many parts of Arizona which are universally recognized as Lower Sonoran, and if this valley is held to be tropical, it becomes quite impossible to define the Tropical zone in any terms of value to the agriculturist. However, in his text, Dr. Merriam speaks of this region as "dilute arid tropical," and in the admirable "Handbook of Birds of the Western United States," by Florence Merriam Bailey (1902), he has provided a map in which the Tropical is restricted exactly as proposed by Professor Townsend.

Fig. 19. Vegetation in the tropical zone.

Other considerations.

The amount of sunshine in different parts of the United States is controlled by humidity rather than by temperature, and does not follow the isotherms. It must be remembered that the same clear sky, which permits the warmth of the sun to reach the earth during the day, also permits rapid radiation at night, and consequently the sunniest localities are liable to late spring frosts. Taking as an example the percentage of clear sky in April, 1904, as shown by a map in the Monthly Weather Review, we find that it is over 80 per cent in an area, including the greater part of Arizona and much of New Mexico, but less than 40 per cent in a large part of Oregon, and less than 50 per cent in a considerable area of southern Texas. It results that in the arid southwest the days are hot and the nights cool, especially in the spring, and that the deciduous fruits suffer at times very severely from frosts. The native vegetation, except the winter and spring flora already mentioned, holds back, and then comes out very rapidly when the danger from frost is over; but the introduced fruit trees, lured by the warmth of the day, put forth buds and blossoms, and are nipped in consequence. It will be necessary for man to produce varieties of fruits specially adapted to meet these peculiar conditions, in order to be wholly successful.

It must also be noted that the southern limit of snow is not even across the country, but rises rapidly westward, so that, speaking generally, the western lands, as well as the southern, are bare in winter, and not covered by snow, as are those in the east, and especially northeast.

Still another very important factor is the time of year when most moisture falls. This differs greatly in different regions, and necessarily has a profound influence on agricultural operations. A. F. W. Schimper, in his great work on plant geography, gives a rain-chart of the earth, in which North America is shown to contain five areas differing in this respect. In the Monthly Weather Review for October, 1904, Professor V. Raulin gives a similar map for the United States, differing in details, and showing only four distinct areas. In general terms, it may be said that west of the 115th meridian the summer is very dry, the autumn and winter rainy; in Arizona and the country northward and some distance eastward, the rain falls in the winter and spring; in the south, excepting the Atlantic coast, and most of the Rocky mountain region, the spring is rainy, the summer comparatively dry, and the fall especially so; in the northeastern and most of the northern states east of the Rocky mountains, as well as the Atlantic coast, all seasons are humid, but most rain falls in summer.

This account may impress the agriculturist as indefinite and unpractical; but all we can do in the present state of our knowledge is to set forth the problem, illustrating it by concrete cases here and there. The article may suggest the kind of work that needs to be done.

AGRICULTURAL FEATURES OF THE UNITED STATES, CANADA, AND NEWFOUNDLAND

The best view of the agricultural capabilities of the entire country is to be secured from the opinions of judicial persons living in all the different parts of it. Such a view is attempted in the following symposium. It is impossible, of course, to cover the agricultural adaptabilities of the different states and provinces in the brief space allotted to each; but the reader will catch the drift and discern the larger features. In every article, also, he will be impressed with the hopefulness for better things. Every region has superlative advantages of some kind.

1. NEWFOUNDLAND, AND EASTERN CANADIAN PROVINCES

COLONY OF NEWFOUNDLAND. (By *Judge Prowse.*) The possibilities of Newfoundland as an agricultural country have been frequently misrepresented. The country is not a barren wilderness with an arctic climate. There is plenty of really good agricultural land in the island. Better-tilled lands and finer crops of cabbage, potatoes, turnips, beets, oats, barley and hay than are found near St. Johns, cannot be seen anywhere. The best land is situated in the valley of the Codroy, along the banks of the Little and Great Codroy rivers. The lower part of this valley is about ten miles broad, but up the river the hills converge, and about twenty-four miles inland its width is two miles. Along the river banks rich alluvial soil is found, capable of growing all kinds of crops. The upland soil is lighter and free from stones. Farther back on the hills excellent grazing land is to be had, and many thousand head of cattle could be fed there.

Fig. 20. Haying in Newfoundland.

The soil in St. George's Bay district is very fertile, and land has been under crop for sixty years without manure. The good land extends twelve miles from the coast into the hills, and along the coast thirty-six miles from the highlands to St. George on the south side of the bay. On the north side, from Stephenville to the Creek, a distance of about fifteen miles, the soil is good, and extends to the foot of the hills, on an average of two miles from the coast. Some very good land is also to be found at Spruce brook and George's pond. Humber valley, Deer lake and Grand lake country contain many square miles suitable for agriculture; the soil on the banks of the rivers and streams is very rich, having a depth of four to ten feet. The surrounding hills are well-adapted to sheep and cattle-raising. The Exploits Arm and valley and Red Indian lake abound in good agricultural land. Although the soil is not so rich as the Codroy valley land, it is capable of producing good crops, and a ready sale will be had near at hand for produce raised, at the lumber camps around this section. Good land is also met with in abundance at Gander river, and along the banks of the smaller rivers, around the heads of most of the bays, and on some of the islands. Between St. Mary's and Placentia there are thousands of acres of well-watered grazing ground. There is also a vast amount of wild pasture for cattle on the barren tracts in different parts of the island. The opportunity for extending the cattle-raising industry is very great.

The Exploits, Gander, Gambo and Humber valleys

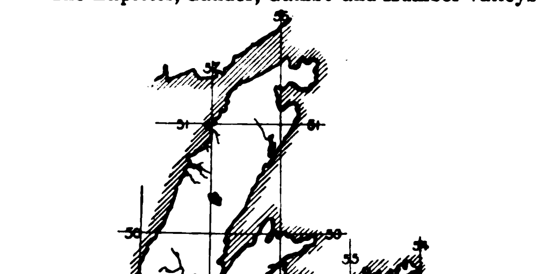


Fig. 21. Agriculture in Newfoundland.—A (oblique shading downward to the right), general agriculture; B (oblique shading to the left), timber; D, sheep land; G, good land for tillage. St. George bay is on the southwestern point of the island (just above 48°). The Codroy rivers flow into the Gulf of St. Lawrence just south of this bay. The Humber valley, Deer lake and Grand lake lie to the northeast from St. George bay (at A). The Exploits valley and Red Indian lake (B in the center of the island) drain northeastward into the ocean. Gander and Gambo valleys lie southeast of this. St. Mary's bay is on the extreme southeastern shore (between G and D). Placentia bay is the large bay just west of this, and Trepassey bay is the small one to the east on the very point.

contain an immense area of good pine, fir, beech and spruce. Lumber mills are at work in all the sections, and most of the pine lands are under lease. At St. George and Codroy, large white and yellow birch, fir and spruce abound. The chief forest product is lumber, of which there was an export of $270,332 worth in 1903–1904, to the United Kingdom. On the banks of the rivers, around the arms of all the bays,

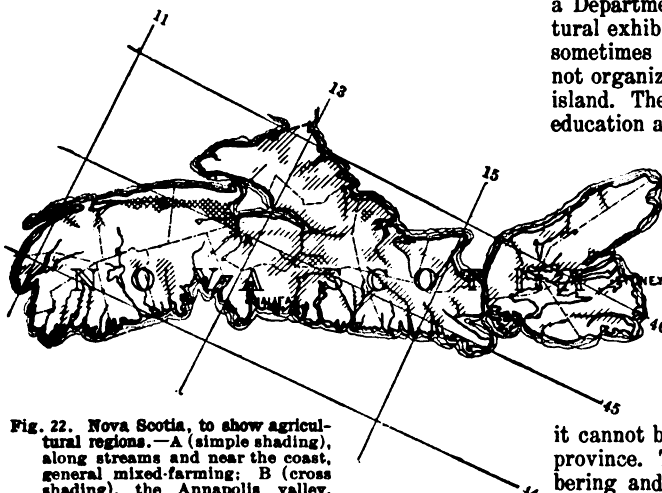


Fig. 22. Nova Scotia, to show agricultural regions.—A (simple shading), along streams and near the coast, general mixed-farming; B (cross shading), the Annapolis valley, noted for fruit.

and in many other sections, the country is thickly wooded. Spruce is particularly plentiful, and the outlook is for the island to become a great pulp and paper country. Syndicates are already entering and erecting plants. The abundance of pulp wood, good water-power, and facilities for transportation make the growth of this industry certain.

Newfoundland is specially adapted for a great sheep country. There are grassy downs inside of Branch St. Mary's Bay, excellent upland pastures between St. Mary's and Trepassey, and in numbers of other places around the island, on which, with a little aid, thousands of sheep could be kept all the year round. A good, hardy breed of sheep is required. Instead of 80,000 sheep, Newfoundland should have millions. It has been well said that the future prosperity of Newfoundland lies in sheep and herrings; coal should be added. According to the Census of 1901 the agricultural stock and produce in Newfoundland was:

Wheat and barley—bushels	824
Oats—bushels	10,773
Hay—tons	53,883
Potatoes—barrels	541,766
Turnips—barrels	65,298
Horses	8,851
Milch cows	14,135
Other horned cattle	18,607
Sheep	78,025
Swine	34,547
Fowls	207,251

The acres of improved land in Newfoundland are now 100,000, valued at $8,000,000. In pasture there are 40,000 acres, worth $800,000. The total value of the farm stock is $2,020,000. The chief sources of income are: Hay, about 60,000 tons, worth $1,200,000; potatoes, 541,766 barrels, worth $1,083,532; turnips, 65,298 barrels, worth $65,298; cabbage, worth about $50,000; and oats, 12,000 bushels, worth $7,200.

There is a Board of Agriculture, with headquarters at St. Johns. Its main work is to import stud animals—stallions, bulls, rams and boars. There is also a Department of Agriculture and Mines. Agricultural exhibitions are held occasionally in St. Johns, sometimes in the outposts. This work, however, is not organized, and is one of the great needs of the island. There is also a great need for agricultural education and the distribution of information about the farming interests suited to the island. There are no model farms or experiment stations under governmental control.

NOVA SCOTIA. (By *F. L. Fuller.*) Nova Scotia, the most easterly province of the Dominion of Canada, consisting of the peninsula of Nova Scotia proper and the island of Cape Breton, is a country richly endowed with varied natural resources, but it cannot be said to be essentially an agricultural province. The coal, iron, gold, gypsum, lime, lumbering and fishing industries engage the attention of a large proportion of the population. This population affords a good local market, which at present is not supplied by Nova Scotia farmers. The province is intersected by high hills, and indented with deep bays and harbors along the coast-line. The interior of the province is covered with a network of lakes, which find their outlet through numerous small rivers. It is along the valleys formed by these rivers that the best agricultural lands are found. In some counties of the province there are also large tracts of very productive land that have been reclaimed from the tidal waters of the Bay of Fundy.

The chief types of agriculture are fruit-growing, stock-raising, and dairying.

Although fruit can be grown to some extent in most of the agricultural sections of the province, it is at present confined, as a commercial industry, to the famed Annapolis Valley, a strip of land about eighty miles in length and five to ten miles wide, extending from Windsor to Annapolis and lying between the North and South Mountains. There are exported from this valley, annually, upwards of a half million barrels of apples, and the possibilities are far in excess of this. Smaller fruits and potatoes also form an important part of the output of this section. The special adaptability of this section to fruit is due rather to favorable climatic conditions than to soil.

Stock-raising is largely confined to the vicinities of the diked marsh lands and the intervals along some of the larger rivers, while dairying and mixed-farming are found, for the most part, in the outlying and less favored sections. A moist climate, abundance of pure water and freedom from extremes of temperature make the province an ideal place for dairying. The conditions are also exceedingly well adapted to sheep-farming.

The chief drawback is a long winter and a rather short growing season. At the same time, vegetation is rapid and the extremes of temperature are not very great, the thermometer seldom falling under ten degrees below zero, or rising over ninety degrees above. The average temperature for winter is about twenty-three degrees and for summer about sixty-one degrees Fahrenheit.

The map (page 30) indicates the principal agricultural sections of the province. In addition to those marked, there are numerous small localities where agriculture is practiced with varying degrees of success, but these localities are so isolated from the principal sections of the province that, while all together they amount to a considerable area, yet individually they cannot be said to contribute greatly to the agricultural products of the province.

The total area of Nova Scotia is 13,483,691 acres. Of this, according to the Census of 1901, 5,080,901 acres are in farms, of which 1,257,460 acres, or 24.7 per cent, are improved. The total value of the farm property is $86,183,871. The values of the chief sources of income are: Dairy products, $2,885,997; live-stock, $1,427,777; fruit and vegetables, $1,407,369; dressed meats, $1,247,358.

With the aid of the government, a great deal of agricultural educational work is being done. There is a well equipped agricultural college at Truro, in the center of the province. Many agricultural societies have been formed, whose principal aim it is, with the aid of a government bonus, to purchase pure-bred sires and thus keep up the standard of the live-stock. In addition to this, the government has adopted the policy of making frequent importations of pure-bred stock, especially horses, cattle and sheep, which are distributed throughout the agricultural sections. There have also been set out from one to three illustration orchards of about two acres each, in every county of the province, with a view of demonstrating the possibility of extending the fruit-growing area beyond the limits of the Annapolis Valley.

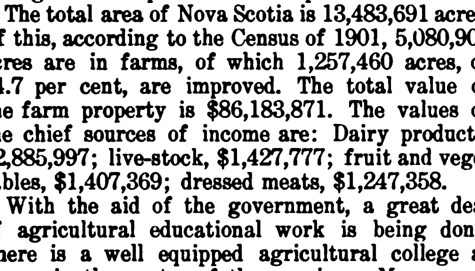


Fig. 24. Prince Edward Island.—The agriculture is generally distributed.

PRINCE EDWARD ISLAND. (By *J. C. Ready.*) The "Garden of the Gulf," as Prince Edward Island has been familiarly and not inappropriately called, is the most densely populated province in the Dominion of Canada. Its extremely fertile soil and park-like landscape have earned for it this name. Though smallest of the provinces, it is doubtful whether any other Canadian area is so uniformly capable of the continuous production of such large quantities of agricultural commodities. For years, the somewhat injurious custom of growing and selling oats and potatoes has been practiced, but this has now given place almost entirely to the dairy industry on the coöperative system. Live-stock raising goes hand in hand with the dairying, while fruit-growing seems destined to take a prominent place in the economy of the province.

Fig. 23. Harvest scene in Prince Edward Island.

Agriculture must always remain the chief industry of Prince Edward Island. Of minerals it has none, and the forests have already been largely removed; so that, with the exception of the fishing business, the province must depend for progress on the proper husbanding of the fertility of the soil. The soil and climatic conditions are such, however, as to make possible an unexcelled quality of horses, cattle, poultry, dairy products and fruit.

Lack of markets has never presented any serious problems to island producers or legislators. British requirements provide for the consumption of the butter, cheese and fruit. The mutton, beef and potatoes find ready sale in American markets, and the surplus pork, poultry and eggs are consumed in the adjoining provinces. But the winter transportation problem has long presented its difficulties. For months the Straits of Northumberland, which separate the island from the mainland, are blocked with ice. Two large federal government boats of the ice-breaking class have been provided, but these often fail to keep up continuous communication with the mainland. Prospects at present indicate that a heavier ice-breaking steamer will be placed in service, and the inconvenience of interrupted communication be overcome. Even should this boon be procured, the frequent change of freight from rail to boat and from boat again to rail must decrease the profits to the farmer and operate against the quality of island produce.

France and the British Isles have given to the population of the province sturdiness, intelligence and capacity sufficient to warrant stability and future progress. Heredity has bestowed a conservatism consistent with these qualities, although this characteristic, together with the limitations of the provincial boundary and a self-constituted environment, militate somewhat against the rapid introduction of newer methods and ideas.

The total area of Prince Edward Island is 1,397,991 acres, of which 1,194,508 acres, or 85.44 per cent, are occupied. Of this, 726,285 acres, or 60 per cent, are improved. Of the unimproved area, 350,366 acres are in forest. There are 13,199 farms on the island. The total value of the farm property, according to the Census of 1901, was $30,626,713. The total gross value of farm products for 1901 was $7,467,567. The four chief sources of income are fruit, meats, poultry and dairy products.

The agricultural affairs of Prince Edward Island are under the direction of the Department of Agriculture, with headquarters at Charlottetown. The department is in charge of a Commissioner of Agriculture, who is nominated by the government and appointed by the people, and who has direct charge of the agricultural interests of the province. He is assisted by a professor of agriculture, who acts as superintendent of farmers' institutes and of the provincial farm, and takes charge of the agricultural education generally. A small amount of experimental work is conducted on the provincial farm, but the chief object of the farm is the supplying of pure-bred stock for the farmers. Some experimental work is undertaken in horticulture in nine model orchards that have been planted by the government at different points throughout the province. The annual exhibition is held in Charlottetown, being operated by a private corporation which receives an annual grant from the provincial government. The province is well organized under a farmers' institute system. Besides this organization there is the Provincial Fruit Growers' Association and the Dairymen's Association of Prince Edward Island. Agriculture is taught in the Prince of Wales College, which is the provincial institution for the training of the public school teachers.

NEW BRUNSWICK. (By *A. G. Dickson.*) General farming is followed throughout the province of New Brunswick, including the production of hay, grain, fruit, stock and dairy products. The southwestern part of the province, because of its abundance of marsh hay, is best adapted to stock-raising, while dairying is successfully practiced throughout the middle of the province.

The rainfall is abundant all over the province. The soil, especially in the river valleys, is very productive. No country has better transportation facilities than New Brunswick. With its great stretch of seacoast, its many navigable rivers and lakes, its extensive railways stretching in all directions and its good roads, no inhabitant finds it difficult to place his products on a good market.

The population consists mainly of a sober, industrious and intelligent people. A noticeable improvement in agriculture has been made in the last decade.

The magnificent extent of forest regions and the great fishing privileges afforded by the coast and numerous rivers has, in the past, to some extent retarded agriculture, as farmers have been induced to neglect their farms in pursuit of these industries.

The improved methods of farming which are being adopted by the people, the growing of more clover and thereby increasing the fertility of the soil, the marketing of the finished product rather than the raw material, the raising of better live-stock with better care and feeding, must tend toward future development.

The total land area of New Brunswick is 17,863,266 acres. Of this, according to the Fourth Census of Canada (1901), 4,442,594 acres, or 24.87 per cent, were occupied as farms, of which 31.67 per cent was improved. There were then 35,051 farms of five acres or above. The total value of the farm property was $51,338,311. The total value of the farm products was $12,873,480. The four chief sources of income were: Field crops, 61.06 per cent, including grains, hay and potatoes; dairy products, 16.83 per cent; meat and other animal products, 8.93 per cent; live-stock, 6.12 per cent.

There is no agricultural college in New Brunswick. The New Brunswick government contributes to the support of an agricultural college located at Truro, Nova Scotia, the adjoining province. The Experimental Farm for the Maritime Provinces, supported by the Dominion government, is located at Nappan, Nova Scotia. New Brunswick has a Department of Agriculture with headquarters at Fredericton, in charge of a Commissioner appointed by the Lieutenant-Governor in Council. Its functions are to have a general oversight of the agricultural industries throughout the province. It

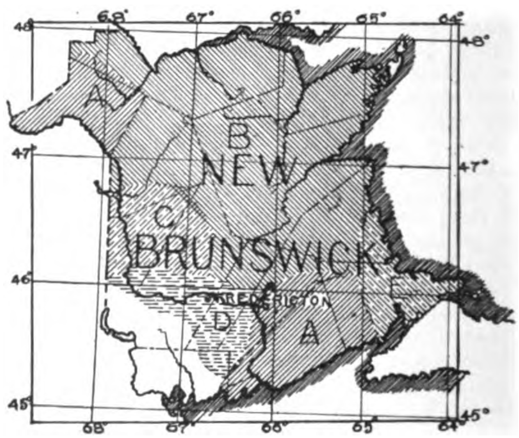


Fig. 25. Leading agricultural distribution in New Brunswick. —A, dairying; B, wheat; C, hay and grain; D, fruit; E, stock-raising.

assists financially and by advice the dairy industry, fruit-growing, live-stock-raising, and any feasible expenditure that will advance agriculture. It also assists and controls to some extent the following associations: The Farmers' Institute, Farmers' and Dairymen's Association, Fruit-growers' Association, Bee-keepers' Association, Live-stock Breeders' Association, Miramichi Agricultural Exhibition Association at Chatham, and a number of local agricultural societies. There is a provincial fair held annually, alternately at St. John and Fredericton.

QUEBEC. (By *G. A. Gigault.*) The agricultural interests of Quebec are advancing rapidly, in keeping with the rapid increase in the population. The progress between the census years of 1891 and 1901 has not only continued unabated but has increased. The value of dairy products in the factories of the province was $2,918,527 in 1891 and $12,874,377 in 1901, showing an increase of 341 per cent. The increase in the number of its factories represents 68.5 per cent of the increase for the whole of Canada. Dairying and hay- and grain-growing are practiced in every part of the province. Market-gardening flourishes near the cities, especially in the neighborhood of Montreal. The raising of beef-cattle is a business of considerable importance in the eastern townships. There are numbers of orchards in the Montreal district and in the eastern townships, where large quantities of apples, pears, cherries, and other fruits are grown. Fruit-growing is less prosperous in the district of Quebec, where the climate is colder; but even here there are good orchards of apple, plum and cherry trees. Excellent Swedish turnips are produced for the table. They are in great demand on the Montreal market and elsewhere.

As England imports great quantities of butter, cheese, bacon, beef-cattle and fruit, and as all these products are admitted duty free, Quebec naturally seeks to supply this market. The transportation by water greatly facilitates this trade.

Formerly, a large part of the agricultural produce was sold on the American market; but this trade has diminished because of the almost prohibitive duties imposed by the American government, and development of the agricultural resources of the American republic. The English market has become more profitable. While striving to enlarge the dairy industry, the province is actively engaged in improving its breeds of horses, and in advancing its fruit and bacon interests.

The total land area of Quebec is 222,080,000 acres. Of this, according to the Census of 1901, 14,444,175 acres were occupied, of which 7,439,941 acres, or 51 per cent, are improved. The total value of the farm property was $436,076,916. The total value of the farm products was $85,034,401. The values of the chief sources of income were: Field crops, $44,851,108; dairy products, $20,207,826; meats, $8,006,328.

The circulation of agricultural publications is increasing. The "Journal of Agriculture and Horticulture," published by the Department of Agriculture, has more than 63,000 subscribers.

The Department of Agriculture of the province has its headquarters in the city of Quebec; it is in charge of the Minister of Agriculture. The agricultural and dairy societies, the agricultural and dairy schools, the farmers' clubs, the fruit-growers' associations, the inspection of butter and cheese factories, and everything that relates to agriculture are under its control. The province has two agricultural schools, Oka and Ste. Anne-de-la-Pocatière. There is also a large dairy school at St. Hyacinthe, with a farm attached. The Macdonald School of Agriculture, with the finest outfit of its kind in the Dominion, is to be opened in the near future at Ste. Anne de Bellevue. Last year 575 farmers' clubs received grants from the Department of Agriculture. The minimum of the grant is $25, and the maximum $50. The farmers' institutes are held through the farmers' clubs. To be entitled to a grant, a club must hear at least one lecture on agricultural matters during the year. Eleven lecturers are employed by the Department. A club may be organized in any parish or township. The leading agricultural associations in the province are: Quebec Dairymen's Association, Quebec Pomological Society, the Eastern Townships, Three Rivers and Quebec Exhibition companies. A provincial fair is held every year at Sherbrooke, under the control of the Eastern Townships Exhibition Company. The province has also seventy-four county agricultural societies and several local horticultural societies.

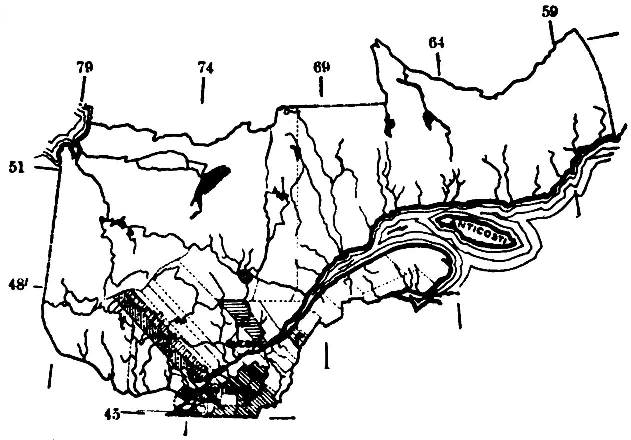


Fig. 26. The Province of Quebec.—The upper parts of the province are unsettled. In the southwestern part, about the cities of Quebec and Montreal, the agricultural industries are developed. About Montreal, near the southern boundary, market-gardening and fruit-growing are prominent. In Montcalm and Joliette counties, E, H, tobacco is grown. In L'Islet county, F, above the city of Quebec, there are also plum orchards. In the eastern townships between, Montreal and Quebec and south of the St. Lawrence river, beef cattle and apples are important products. In Quebec county, C, Swedish turnips are prominent. The parallel dotted lines extending outward from the St. Lawrence River are boundaries of counties.

ONTARIO. (By *C. A. Zavitz.*) The types of agriculture chiefly represented in Ontario are stock-raising and fruit-growing. Of these, the former is decidedly the more important, and is subdivided into pure-bred stock-raising, dairy-farming, beef production and mixed-farming. It is difficult to describe just what is meant by mixed-farming, as it includes different lines of work, several of which are conducted simultaneously on each farm. Some of its chief factors are seed production, hog-raising, sheep-raising, poultry-raising, bee-keeping, sugar-beet production, potato-growing, flax-growing, the production of hops, and other enterprises.

Fruit-farming is confined mostly to the shores of

Lake Erie and Lake Ontario, but stock-raising is practiced generally throughout the province. The dairy industry is developed principally in Oxford county, in southwestern Ontario, and throughout the district lying between the Ottawa and the St. Lawrence rivers, in the eastern part of the province. Pure-bred stock is produced in many counties, among which may be mentioned Ontario, Middlesex and Wellington. For the production of beef-cattle, the counties of Huron, Middlesex, Bruce, Grey, Perth, Lambton and Kent are among the most prominent, all in the south-western part. Essex and Kent are noted for the development of the swine industry. The growing of hops is prominent in Prince Edward county, and of sugar-beets in Waterloo, Kent, Essex and Lambton counties. The remainder of the province is not easily classified, as the mixed-farming is so subdivided that there is a great blending of the various branches.

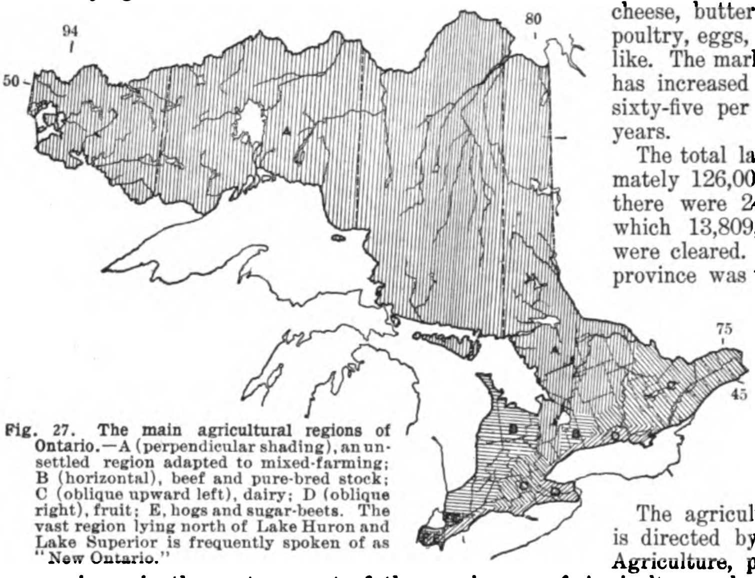


Fig. 27. The main agricultural regions of Ontario.—A (perpendicular shading), an unsettled region adapted to mixed-farming; B (horizontal), beef and pure-bred stock; C (oblique upward left), dairy; D (oblique right), fruit; E, hogs and sugar-beets. The vast region lying north of Lake Huron and Lake Superior is frequently spoken of as "New Ontario."

Ontario is essentially an agricultural province. It is especially suitable for the production of live-stock of high quality. The soil and climate are conducive to the successful cultivation of cereals, root-crops, and many of the important fodders, including field peas, rape, clover, and, in some sections, corn, sorghum and alfalfa. The cultivated grasses, which are sown, and the Canadian and the Kentucky blue grasses, which grow naturally, make excellent pastures. The abundant supply of stock feed, the natural distribution of pure water, and the very healthful climatic conditions are among the important features that make the province of Ontario so suitable for the live-stock industry.

The United States customs tariff on cereals and hay has been a blessing to the farmers of Ontario. It has compelled them to feed the great bulk of their crops to their own farm stock. This has resulted in a great development of the live-stock industry, an improvement in the fertility of the land, and the establishment of an excellent market in Great Britain for animal products.

It is likely that the future development of Ontario agriculture will be along the line of a more intensive system of farming, a still further improvement of the live-stock interests, and a greater export trade of concentrated products, such as cheese, butter, bacon, hams, beef, mutton, poultry, eggs, seed peas, clover seed, and the like. The market value of Ontario live-stock has increased sixty million dollars, or fully sixty-five per cent, within the past seven years.

The total land area of Ontario is approximately 126,000,000 acres. Of this, in 1904 there were 24,138,846 acres in farms, of which 13,809,368 acres, or 57 per cent, were cleared. The number of farms in the province was then 175,000. The total value of the farm property was $1,127,915,338. The total value of farm products, exclusive of crops fed to live-stock, was $180,000,000. The chief sources of income were: Cattle, $26,342,872; swine, $22,665,164; cheese, $12,908,118.

The agricultural organization of Ontario is directed by the Ontario Department of Agriculture, presided over by the Minister of Agriculture, who is a member of the legislature and has a seat in the Provincial Cabinet. The Deputy Minister supervises the work, which is subdivided into various branches. The Agricultural College and Experimental Farm are situated at Guelph. The Macdonald Institute is part of the college, devoted to domestic science, nature-study and manual-training. This institution is maintained by annual grants of the legislature. The well-equipped Experimental Farm at Ottawa is under the direction of the Dominion government. There are three dairy schools maintained by the Department, at Guelph, Kingston and Strathroy. Two dairymen's associations are organized. The Department maintains a staff of over thirty dairy instructors, who go from factory to factory giving instruction, and holding meetings of patrons. Six provincial live-stock associations are supported,—horse, sheep, swine, cattle, and two poultry associations. These associations, under the Provincial Director of Live-Stock, conduct two winter fairs, at Guelph and Ottawa. A provincial fruit-growers' association is assisted. The Department also maintains a series of experimental fruit farms, and conducts spraying experiments in various fruit-growing sections. Under the Provincial Superintendent of Agricultural Societies, expert judges are sent to exhibitions, and the educational features encouraged. Four hundred agricultural and horticultural societies receive grants through the Department. The Superintendent of Farmers' and Women's Institutes directs organization in all parts of the province, and arranges meetings. The institutes receive annual grants, and the services and expenses of speakers are paid by the Department. The Ontario Bee-Keepers' Association receives a grant, and the services of an Inspector of Foul Brood are paid for by the Department. An annual grant is made to the Provincial Entomological Society. The Department at Toronto prints and publishes all the reports and bulletins in connection with the above associations, those of the Agricultural College, and statistical reports of crops and farm operations. The net appropriations for agricultural work in Ontario for 1905 amounted to $362,000, in addition to $39,000 voted under Capital Account.

2. NEW ENGLAND

MAINE. (By *S. L. Boardman.*) The variety of soils, range of crop production, water supplies, climatic conditions, stock husbandry and markets favor a high type of agricultural development in Maine. In classification of soils, the state possesses clay loam, light or friable sandy loam, mountain interval, river-bottom interval, salt marsh (diked) and fresh meadow. The surface is irregular and picturesque—from the mountains of the mid-interior to the beautiful beaches of its extended coast. There are over 5,000 rivers and streams sufficiently large to be noted on the state map, and 3,800 square miles of lake and pond surface. But two other states in the Union have a larger area of water surface. Its forest area comprises 23,700 square miles, or seventy per cent of its total area. Government forestry experts estimate that there are about 12,000,000 acres covered with merchantable forest.

Agricultural lands of greatest value are in Aroostook, Kennebec, Androscoggin, Somerset and Franklin counties, in the northern, western and western-central parts of the state. Outside of Aroostook, its northern county, the best farmed sections are those in the central part of the state, along its large rivers where water-powers have been most improved, in the regions of its greatest lakes, and where its railroad systems have been most completely developed. Farms in the valleys of the Kennebec, Androscoggin and Sandy rivers are the best lands for the cereals; the uplands are fine for grazing and orcharding: on the clay bottoms hay is the chief crop.

The general type of agriculture is that of mixed husbandry, embracing stock-raising, dairying, orcharding, and the growing of Indian corn, grass and the grains. In specialties, the leading systems are potato-growing, orcharding, dairying, the growing of sweet corn for packing factories, and truck-farming in the vicinity of the larger cities and leading summer resorts.

The climate is very uniform, healthful, and favorable to agriculture. The cold is not so severe in winter as it is at points in the west and northwest of the Union in corresponding latitudes. This is due to the alleviating influence of the surrounding ocean, the effect of which, though it be to lower the mean of the year, raises it for the winter. For a period of thirty-five years, ending in the year 1904, the mean temperature for January was sixteen degrees Fahr., and for July, sixty-seven and one-tenth degrees. From records kept for thirty-two years, the mean precipitation is 43.24 inches. Evenness of distribution in rainfall is an important condition to the state's productiveness.

The hay crop is about 1,100,000 tons, outranking that of all other New England states. Sixty-four corn-packing factories require the product of 15,000 acres of sweet corn annually. Apples have a high value for their keeping qualities, and are largely shipped to foreign markets—Glasgow, Liverpool and London. The report of the state assessors for 1904 gave the value of all live-stock as $14,136,662. In thoroughbred stock of all classes, in the best families of coach, work and light-harness horses, the state holds high rank.

Railroads extend to all parts of the state and afford good transportation facilities. The manufacturing centers, large cities, and the growing importance of the now famous summer resorts, Bar Harbor, Kineo, Poland Spring, the lake sections, and the

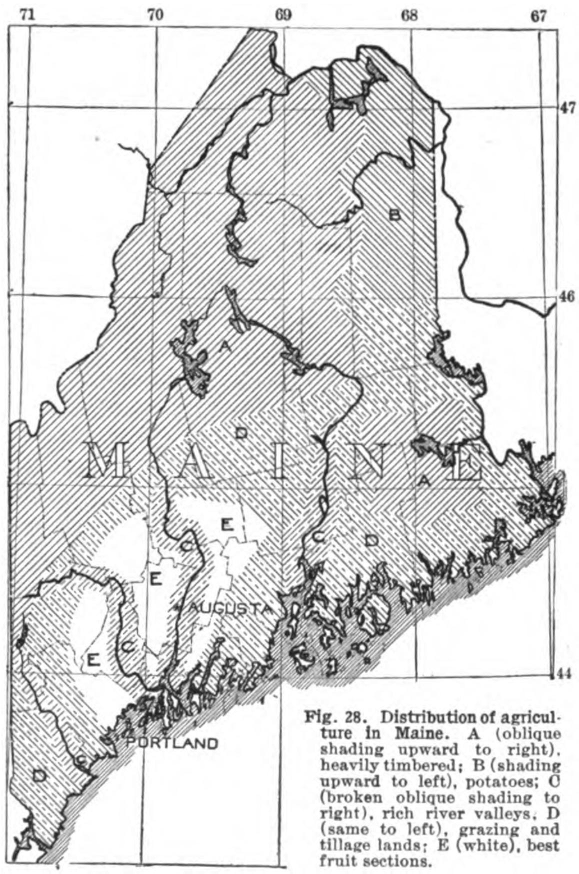


Fig. 28. Distribution of agriculture in Maine. A (oblique shading upward to right), heavily timbered; B (shading upward to left), potatoes; C (broken oblique shading to right), rich river valleys, D (same to left), grazing and tillage lands; E (white), best fruit sections.

beaches, stimulate agriculture in the lines of truck-farming, small-fruits, poultry, egg production and early lambs.

The Northern Maine Seaport railroad from Lagrange Junction to Stockton on Penobscot Bay insures coast markets without limit for seed and table potatoes. Tens of thousands of car-loads annually find their way out all rail, and are distributed to every state and territory. Stockton harbor is one of the best on the coast. Lines of European steamers also make Portland their fall and winter terminus and take large shipments of apples, while summer steamers at all resort points give good facilities for the summer marketing of truck crops.

It seems probable that future development of the agriculture of the state will be made in the lines of dairy-farming, potato-growing, small-fruits and truck-gardening for summer-resort markets, and in general stock-raising, especially in sheep husbandry.

Fig. 29. A New England farmstead.

The total land area of Maine is 19,132,800 acres. Of this, according to the Twelfth Census Report (1900), 6,299,946 acres are in farms, 2,386,889 acres of which, or 37.9 per cent, are improved. There were then 59,299 farms in the state. The total value of the farm property was $122,410,904. The total value of the farm products was $37,113,-469. The values of the leading products were: Domestic animals, $16,298,422; hay and forage, $10,641,546; dairy products, $8,182,344; vegetables, $4,957,451.

The land grant institution of Maine is the University of Maine at Orono, of which the Experiment Station is a branch. The officers of the various state agricultural associations are connected with the College of Agriculture and the Experiment Station in an advisory capacity. In 1901 the State Board of Agriculture was abolished, and in its place was created a State Department of Agriculture, with a chief executive officer who is Commissioner of Agriculture, with headquarters at Augusta. This officer is director of the farmers' institutes, two of which are held in each of the sixteen counties each year, with larger state meetings making about forty-five in all. The state has a Commissioner of Forestry and a chair of forestry in the College of Agriculture. There are now forty-three incorporated county and local agricultural and horticultural societies, which receive about $10,000 in bounties from the state. There are three state fair associations, a State Pomological Society, State Dairymen's Association, State Horse Breeders' Association, State Board of Cattle Commissioners, and a State Poultry and Pet Stock Association.

NEW HAMPSHIRE. (By *Fred W. Morse.*) Dairying is the foremost agricultural industry in New Hampshire, since dairy farms include over thirty-five per cent of the farm lands, while the mixed farms, and live-stock farms, on which dairying is an important feature, bring the percentage to eighty-five. Less than five per cent of the acreage of the state is included in farms devoted solely to such specialties as vegetables and fruit. A few farms in the southwestern part of the state are devoted to tobacco, and a still smaller acreage is included in florists' establishments.

Hay is the most important crop, occupying more than half of the improved land; but it is nearly all consumed on the farm, and forms a minor item in products sold.

Assuming that the farm income consists of all products not fed to the live-stock, dairy products constitute about one-third of it. Forest products come next in gross value, closely followed by that of animals sold alive or slaughtered. Poultry and eggs nearly equal the preceding source, and are a little in excess of the combined value of potatoes and vegetables. Fruits yield about half the value of the total vegetable product, and are about equaled by hay sold. Grain, wool and maple-sugar are minor products in the state as a whole, but constitute important side lines throughout the western counties.

The physical features of the state affect its agriculture to a marked extent. The surface is hilly and mountainous, and the principal farming regions are therefore in the valleys of the Connecticut and Merrimac rivers and their tributaries, and along the short coast-line. Railroads are confined mainly to the level regions mentioned, as are also manufactures.

In the northern half of the state barely half the area is included in farms; the remainder consists of forest land and bare mountain summits. The summer visitors to this section make a demand for dairy products, poultry, small-fruits and vegetables.

Climatic conditions restrict the peach to the southern half of the state, and hinder the successful growth of corn in Coos county, comprising the northern end of the state.

Dairying is distributed throughout the state, but reaches the highest development in Grafton county, in the center of the state. It is much modified by local conditions of transportation and market. Much of the milk is shipped to Boston, though a considerable proportion is sent to creameries. The live-stock industry is most prominent in the central and western parts. Grafton and Coos counties are large producers of potatoes and oats.

Over ninety per cent of the farms are worked by the owners, and the agricultural population is made up almost wholly of native-born New Englanders. There will be in the future a much less number of hay farms, but practically all other lines mentioned will increase. In the past, there has been a steady decrease in the proportion of improved land on the farms, until it is now less than thirty per cent of the farm area, while of this there is only about one-tenth tilled each year. With extended use of machinery and horse labor, more land can readily be brought under tillage, and an increased production assured.

The total land area of New Hampshire is 5,763,200

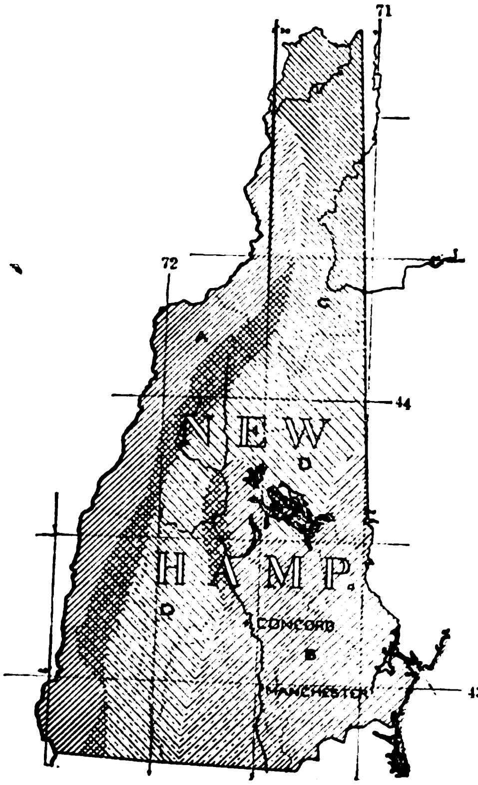


Fig. 30. Leading agricultural areas in New Hampshire. A, best farming region, creameries; B, milk, fruit, vegetables and best farming; C, largely mountains and forests; D, hilly and mountainous, with fewer good forests.

acres. Of this, according to the Twelfth Census Report (1900), 3,609,864 acres are in farms, 1,076,879 acres of which, or 29.8 per cent, are improved. There were then 29,324 farms in the state. The total value of the farm property was $85,842,096. The total value of the farm products was $21,929,988. The values of the leading products were : Domestic animals, $10,062,877 ; hay and forage, $6,336,252 ; dairy products, $5,591,272 ; vegetables, $1,717,-772.

The New Hampshire College of Agriculture and Mechanic Arts, and the Agricultural Experiment Station, are located at Durham. The State Board of Agriculture consists of ten members, appointed by the Governor, and the secretary, who is the executive officer. Its office is at Concord. It has charge of all police and inspectional work relating to agriculture, and conducts the farmers' institutes. The State Grange of Patrons of Husbandry is the strongest and most influential agricultural organization. The Granite State Dairymen's Association, and the New Hampshire Horticultural Society, receive aid from the state, and each holds an annual exhibition and one or more institutes. The State Cattle Commission, made up of three members appointed by the Governor, has charge of all measures for suppression of contagious diseases of live-stock. The Commissioner of Immigration, an appointed official, is engaged in advertising the agricultural possibilities of the state. There is a Forestry Commission, and a New Hampshire Society for the Preservation of Forests. The principal fairs are the Concord State Fair and the Rochester Fair. None of the fair associations receive state aid. There are also several poultry associations holding annual exhibitions.

VERMONT. (By *J. L. Hills.*) Butter and cheese, maple-sugar and syrup, live-stock and lumber are the main agricultural products of Vermont. Its farms carry more dairy cows than do equal areas in any other state. The numbers per farm are exceeded only in New York, New Jersey, Illinois and California, which serve large centers of population. Over 40,000,000 pounds of butter and 5,000,000 pounds of cheese are made annually, the one nearly the equivalent, and the other three times the output of the other five New England States. Most of the butter is made in the northern two-thirds of the state, and of the cheese in the four southern counties. A small but increasing fraction of the milk is sold as such or as cream in southern New England.

The live-stock industry outclasses that of other New England states in total values and in values per farm. The relatively large area enables Maine to make a better gross showing in horses, sheep and poultry; but in all other respects, and overwhelmingly as regards neat cattle, Vermont takes the lead. Few, if any, of the states use so large a proportion of their total agricultural production for stock-feeding purposes.

Vermont has long been a leader in the production of maple-sugar goods. Nearly a third of the world's crop comes from its maple groves, and three-fifths of this is contributed by five of the northern counties. The bulk of this commodity is sold as sugar, but increasing amounts are put up as syrup. Both products have a wide reputation as table luxuries, and Vermont's name is too often used to aid the sale of sophisticated goods that are neither of local birth nor of maple origin. Maple goods are produced in all parts of the state.

More than half the total area is in forest, mostly second growth. The contour of state lines is mainly determined by the topography. The Green Mountain system occupies most of the territory outside of the Champlain and Connecticut valleys, forming a great Y facing north. These mountain slopes are mostly covered with forest growths, which have been and are a source of wealth.

Apple-orcharding in the Champlain Valley, merino sheep and Morgan horse-breeding in Addison county, in the western part of the state, and tobacco-growing in the lower Connecticut valley in the southeastern part are localized industries of importance.

New York, as well as Boston and other southern New England centers, are readily reached by rail, while Lake Champlain and the Hudson River furnish water communication. The 33,000 Vermont farms are mainly occupied by owners, only one in seven being farmed by tenants. The French Canadian is frequent, yet the old New England stock is still in the ascendant. A distinctly hopeful attitude as to the future of Vermont agriculture is more in evidence than it was a decade ago. Its development seems likely to be along the lines of increased dairy husbandry, renewed activities in the raising of cross-bred sheep and of horses of roadster type, and, in the event of the enactment of adequate national pure food legislation, of a marked revival of the maple industries.

The total land area of Vermont is 5,846,400 acres. Of this, according to the Twelfth Census Report (1900), 4,724,440 acres are in farms, 2,126,624 acres of which, or 45 per cent, are improved land. There were then 33,104 farms in the state. The total value of the farm property was $108,451,427. The total value of the farm products was $33,570,892. The values of the leading products were: Domestic animals, $17,373,169; hay and forage, $10,544,825; dairy products, $9,321,389; cereals, $2,446,585.

The land grant college of Vermont is united with the State University at Burlington under the corporate title of the University of Vermont and State Agricultural College, the Experiment Station being

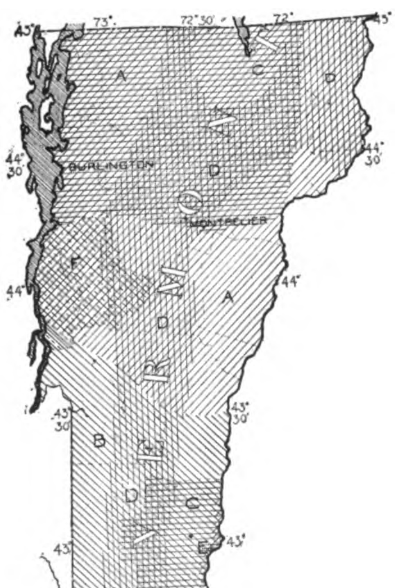


Fig. 32. Distribution of agriculture in Vermont.—A, butter; B, cheese; C, maple goods; D, lumbering; E, tobacco; F, sheep.

a department thereof. The State Board of Agriculture consists of the Governor and the president of the University, ex-officio, and of three active members appointed biennially by the Governor. The conduct of farmers' institutes and the publication of an annual report are its only functions, except that one of its members is ex-officio State Forestry Commissioner. The state fair is at present in a moribund condition. The leading agricultural societies in the state are: Vermont Dairymen's Association, Vermont Sugar Makers' Association, Vermont Horticultural Society, Vermont Bee-keepers' Association, Vermont Merino Sheep Breeders' Association, Vermont Morgan Horse Breeders' Association.

Fig. 31. Characteristic buildings of central and northern New England, the house and barn joined by kitchen and woodshed.

MASSACHUSETTS. (By *George E. Stone.*) The types of agriculture represented in Massachusetts are somewhat varied and of a mixed class, such as are essential for supplying the large home market and which can be profitably grown on its soils for home consumption. Massachusetts, however, is not an agricultural state, as that term is usually employed, and the amount of produce which it exports is unusually small. It depends on the West for its cereals, and large amounts of fruit are imported. Outside of what may be termed general farming, which consists in the production of milk, fodder, potatoes, and the like, there are special industries, as the growing of fruit, tobacco, onions, cucumbers for pickling, asparagus, cranberries and other specialties. Considerable interest is given to the poultry and the dairy industries, the latter having reached, in many instances, a high state of efficiency in recent years. The most important feature in the agricultural development is the intensive agriculture as practiced by market-gardeners. This branch has received considerable attention, and remarkable skill has been developed. Intensive agriculture, as here applied, includes cultivation of outdoor crops, but equally important is greenhouse work. There are many establishments devoted to cultivation of lettuce, cucumbers, tomatoes, beets, rhubarb and other things for the winter market. The yields and profits of intensive agriculture not infrequently show that thirty-six square feet of ground surface in a greenhouse will yield more profit than an acre of wheat, and $1,000 or more per acre is occasionally obtained from outdoor crops. A certain amount of greenhouse products is sent out of the state. There is also extensive floricultural work.

The distribution of various types of agriculture are based, first, on market conditions, and second, on adaptability of the soil. The soil of the Connecticut Valley, in which fine sand and silt predominate, is especially adapted to the production of tobacco and onions, while the sandy bogs on Cape Cod are utilized in growing cranberries. The very dry, sandy regions are employed to a considerable extent for asparagus-growing.

The climatic conditions do not differ much in the various parts of Massachusetts, although some variation in temperature exists, due to location with reference to the seacoast. The maximum elevation above the sea is 3,000 feet. A large part of the farming area is from 200 to 1,000 feet above the sea. There are some variations in the types of soils found in Massachusetts. In general, the percentage of coarse sand increases and clay decreases toward the seaboard, while the percentage of clay increases and of coarse sand decreases toward the western boundary. The variability in sand and clay is quite uniform, although exceptions are found where river valleys cross the state. The western part of the state is mountainous and is well covered with forest growth. In the central part of the state there exists a considerable number of clay hills, or drumlins, the result of glacial action, which furnish rather distinct soil characteristics. These are particularly adapted to pasturage and hay crops. The future development of agriculture in Massachusetts is likely to be along intensive lines, with particular attention given to specialties.

The total land area of Massachusetts is 5,145,600 acres. Of this, according to the Twelfth Census Report (1900), 3,147,064 acres are in farms, 1,292,132 acres of which, or 41.1 per cent, are improved land. There were then 37,715 farms in the state. The total value of the farm property was $182,646,704. The total value of the farm products was $42,298,274. The values of the leading products were: Domestic animals, $14,730,169; dairy products, $12,885,744; hay and forage, $9,056,854; vegetables, $5,546,296.

The land grant is divided in Massachusetts. The College of Agriculture is located at Amherst, and is devoted strictly to agriculture. The mechanic arts are provided for at the Massachusetts Institute of Technology, in Boston; for this purpose the Institute of Technology receives one-third of the original grant. The Bussey Institution, where agricultural experimentation and teaching are pursued, is located at Jamaica Plain, and is a part of Harvard University. Elementary agricultural training, particularly along the floricultural lines, is given at Smith College, Northampton; Mount Holyoke College, South Hadley; Wellesley College, Wellesley; Simmons College, Boston, and some minor institutions. The federal and state experiment stations are located at Amherst, and are under a single management, and known as the Hatch Experiment Station. The State Board of Agriculture is in charge of a secretary, who is elected by the Board. This Board has direct or indirect relationships with farmers' institutes, nursery inspection, bounty money for fairs, the dairy, and cattle bureaus, the Agricultural College and Experiment Station, and agricultural societies. The State Board of Agriculture is composed of thirty-two members, chosen by the incorporated agricultural societies of the state, together with three members appointed by the Governor and Council. There is no single state fair in Massachusetts. The various societies that have representation on the State Board of Agriculture hold agricultural fairs, all under state control, with bounties from the state treasury. There are thirty-two incorporated agricultural societies, nine horticultural societies, six farmers' organized associations, eight farmers' and mechanics' clubs, eighteen farmers' clubs, eighteen poultry associations, and eighteen miscellaneous organizations more or less closely associated with agriculture. There is also a large and well organized Grange, or Order of Patrons of Husbandry. Some of the leading agricultural societies are as follows: The Massachusetts Society for Promoting Agriculture, founded in the eighteenth century; the Bay State Agricultural Society; the Massachusetts Horticultural Society; the Worcester Horticultural Society; the Boston Market Gardeners' Association; the Massachusetts Creamery Association; the Massachusetts Fruit Growers' Association; the Farmers' and Cattle Owners' Association, and the Massachusetts Forestry Association.

RHODE ISLAND. (By *G. E. Adams.*) Many types of agriculture are represented in the state, varying from general farming to the most highly specialized forms of gardening requiring acres of glass for their highest development. The western and southern part is devoted to general agriculture, except in the immediate vicinity of the manufacturing towns and shore resorts, where many small

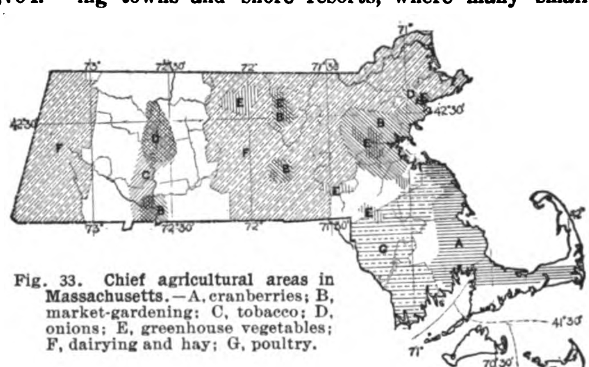


Fig. 33. Chief agricultural areas in Massachusetts.—A, cranberries; B, market-gardening; C, tobacco; D, onions; E, greenhouse vegetables; F, dairying and hay; G, poultry.

market-gardens are found. This section is hilly and for the most part heavily wooded. Lack of proper transportation facilities has prevented the development of the western part. In the northern section of the state the farms are largely devoted to the production of milk, a ready market, easy of access, being furnished by the many manufacturing centers in this part of the state.

Fruit, although not grown exclusively in any part of the state, is produced in larger quantities in the central-northern part than elsewhere, apples being the principal crop grown. There are many other sections of the state that are as favorably located for the production of fruit as this part and which will probably be utilized for these crops within a few years, as there are indications of an awakening along this line in several sections.

Adjacent to the large cities is found the highest agricultural development in the state, namely, market-gardening. The centers of population furnish the requisite markets, and the soil, being a light sandy loam, is the best adapted of any in the state to the growing of early vegetables. This district may be said to extend to and include Bristol county, in the eastern part of the state, where the soil is much heavier and the crops are not so perishable as in the immediate vicinity of the cities.

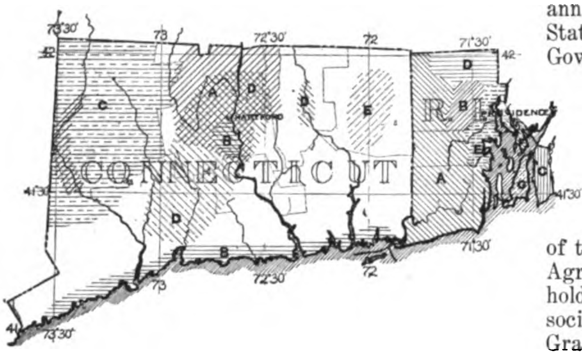


Fig. 34. Connecticut and Rhode Island, to show leading agricultural distribution. *Connecticut.*—A, tobacco; B, onions; C, D, E, fruit, chiefly apples and peaches. *Rhode Island.*—A, general farming; B, fruit; C, poultry; D, milk farms; E, market-gardening; G, early potatoes.

Onions are the staple crop of this section. On the island of Rhode Island large crops of potatoes for the early market are annually produced.

In the southeastern section the poultry industry is a very highly developed specialty, nearly every farm being stocked to its full capacity. Eggs are the principal product sought, the production of meat not being emphasized. The colony system, using small movable houses, is in general use.

The present agricultural development is near the towns, an enlargement of the areas devoted to vegetables both in the open and under glass. Farming under glass is developing very rapidly along the lines of vegetable-growing and floriculture. A ready market is always at hand for the best products of fruit-growing, an industry which holds much of promise for the future.

The general agricultural line that is attracting the most attention at present, and developing rapidly, is the production of hay and straw with the aid of chemical manures. The high prices paid for the crops make their production one which returns an excellent profit for the time and capital employed.

The large manufacturing interests of the state, which employ an ever-increasing proportion of the population, are causing the development of opportunities for the disposal of agricultural products equaled by few states and excelled by none.

The total land area of Rhode Island is 673,920 acres. Of this, according to the Twelfth Census Report (1900), 455,602 acres are in farms, 187,354 acres of which, or 41.1 per cent, are improved. There were then 5,498 farms in the state. The total value of the farm property was $26,989,189. The total value of the farm products was $6,333,864. The values of the leading products were: Domestic animals, $2,281,817; dairy products, $1,923,707; hay and forage; $1,081,482; vegetables, $992,467.

The Rhode Island College of Agriculture and Mechanic Arts, established under the provisions of the Land Grant Act, is located at Kingston. The federal Experiment Station is a branch of it. There is a State Board of Agriculture with headquarters at Providence. This Board is composed of a representative from each agricultural society receiving an annual bounty from the state, one member of the State Grange, and three members appointed by the Governor with the advice and consent of the Senate. The Governor, Lieutenant-Governor and Secretary of State are ex-officio members of the board. This Board has charge of the legal and inspectional work concerning animal diseases and nurseries, and of the farmers' institute work. There is no state fair at the present time, the leading agricultural exhibit of the state being that of the Washington County Agricultural Society, which owns its grounds and holds an annual fair. The leading agricultural societies in the state are as follows: The State Grange, the Rhode Island Horticultural Society, Newport Horticultural Society, Florists' and Gardeners' Club, and Rhode Island Poultry Association.

CONNECTICUT. (By *A. G. Gulley.*) The variations of soil and climate in even this small state are very great, and, in connection with market demands, control the products of localities. The long cultivation of the tillable soil without replenishing the elements removed by crops has left much of it in poor condition; but recent methods are restoring much of it to its original value for farming operations.

Dairying is by far the most important farm industry. The great demand for both milk and butter, not only in the local home markets but in the large cities located just outside the borders of the state, requires a very great supply. The business is so well adapted to the rougher parts of Connecticut, that, when handled with modern methods and appliances, it proves a very profitable branch of agriculture.

Sheep husbandry, once very important, has for some years been much neglected, owing wholly to local conditions. There is at present much promise of improvement, with a probability that sheep-farming will occupy the position in Connecticut agriculture that it did forty years ago.

In farm crops, corn and potatoes rank very high, the former especially, as a supply of cattle food used by the dairymen, through the use of the silo. Tobacco is the leading money crop in Hartford county, in the center of the state, with soil peculiarly adapted to certain kinds, so that its acre value rivals that of any other part of the world. New Milford, in Litchfield county, in the northwestern part, has a similar soil and equal success.

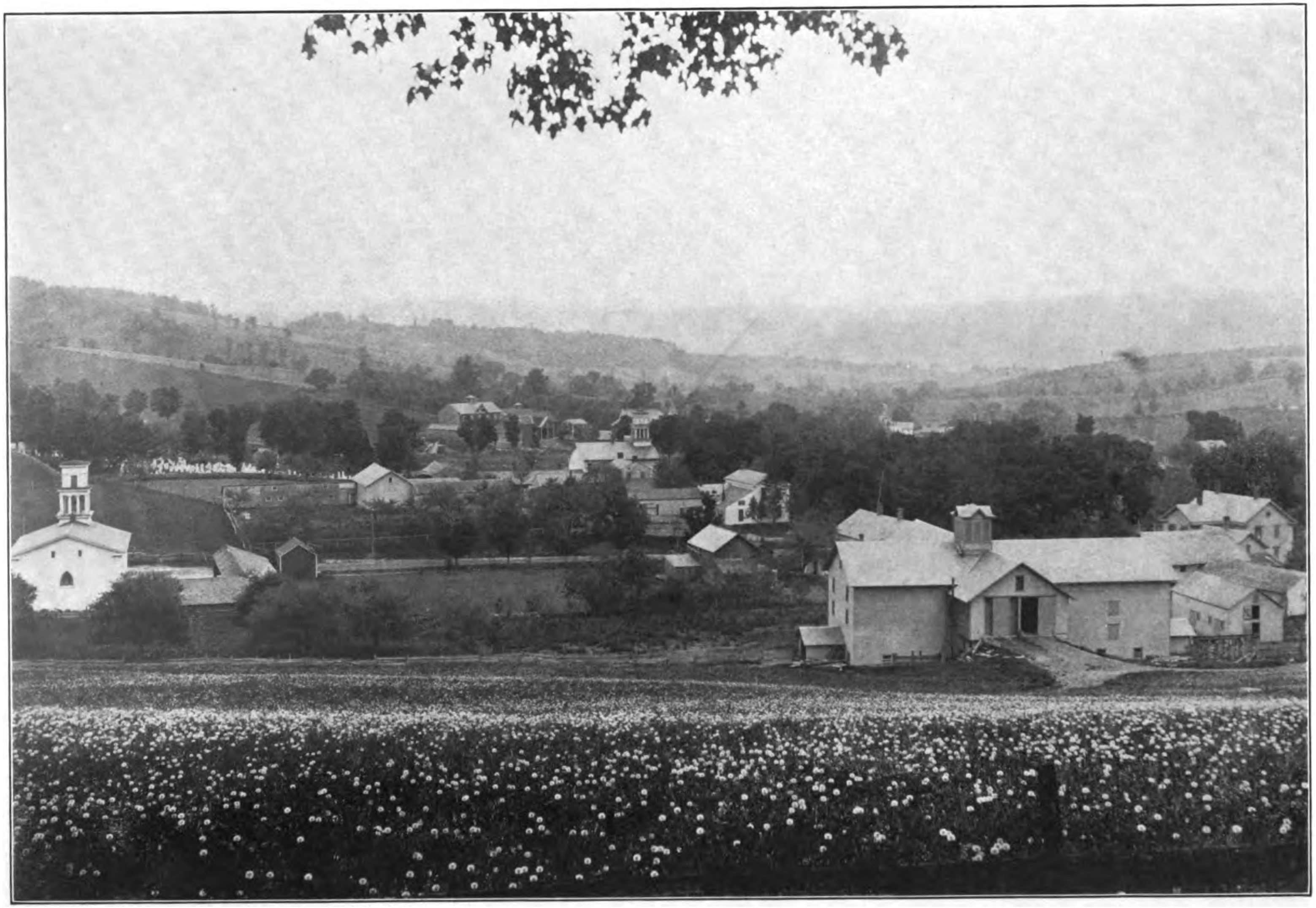


Plate III. A hamlet in the eastern farming country. Lawyersville, eastern New York

Market-gardening and seed-growing in several sections of the state have long been important sources of income. Certain towns, as Wethersfield, in Hartford county, and towns along the Sound in New Haven and Fairfield counties, have for years been noted as onion- and seed-growing localities.

Within recent years fruit-growing has received a wonderful impetus over the state. Apples have long been grown in all parts of Connecticut, but, with the decline of other farm industries, orchards were neglected and very few new ones planted, and the business reached a very low ebb. However, with the new interest taken in other branches of fruit-growing, much more attention is being given to the apple crop, new orchards are being planted, and many of the old ones are having their condition and care much improved. Greater attention is also being given to growing better varieties.

In peach-growing, recent progress has been remarkable. In 1890 there was hardly a commercial orchard in the state, yet in 1905 the crop marketed exceeded half a million dollars in value. Thousands of trees are added each year and with every prospect of profitable results. Nearly all of the other tree-fruits and all small-fruits are now grown and marketed in extensive quantities.

No review of the agriculture of Connecticut would be complete without taking into consideration the handling of poultry. There is hardly a country town, or even a farm, that does not have some surplus products for sale. Within the state are many persons extensively engaged in the business. The adaptability of the work to so many of the population, and the unlimited demand close at hand for the products, have brought the occupation into great prominence.

The total land area of Connecticut is 3,100,800 acres. Of this, according to the Twelfth Census Report (1900), 2,312,083 acres are in farms, 1,064,-525 acres of which, or 46 per cent, are improved land. There were then 26,948 farms in the state. The total value of the farm property was $113,305,580. The total value of the farm products was $28,276,-948. The values of the leading products were: Domestic animals, $10,247,634; hay and forage, $6,001,280; dairy products, $7,090,188; tobacco, $3,074,022.

The Connecticut Agricultural College is located at Storrs. The Storrs Agricultural Experiment Station is a department of it. The well-equipped and efficient Connecticut Agricultural Experiment Station, an incorporated institution, and not connected with any educational institution, is located at New Haven. There is a State Board of Agriculture, organized in 1866, whose duty it is to advance the agricultural interests of the state. Farmers' institutes are conducted by the State Board of Agriculture, the Dairymen's Association and the Pomological Society, acting separately. County and local fairs are held by various societies in all parts of the state, under certain conditions receiving state aid. The leading agricultural organizations of the state are: The State Agricultural Society, State Pomological Society, State Dairymen's Association, Sheep Breeders' Association, The Grange, Forestry Association, Bee-keepers' Association, Creamery Association, Poultry Association. There are State Dairy, Cattle, Horse and Good Roads commissions.

3. NORTHERN AND CENTRAL APPALACHIAN AND SEABOARD STATES

NEW YORK. (By *F. E. Dawley.*) Probably in no other state is the agriculture so varied as in New York. This is partly because of natural conditions and partly because of market facilities. New York leads the states in dairy products, potatoes, hay, farm-forest and other products, and is one of the two or three leading states in horticulture.

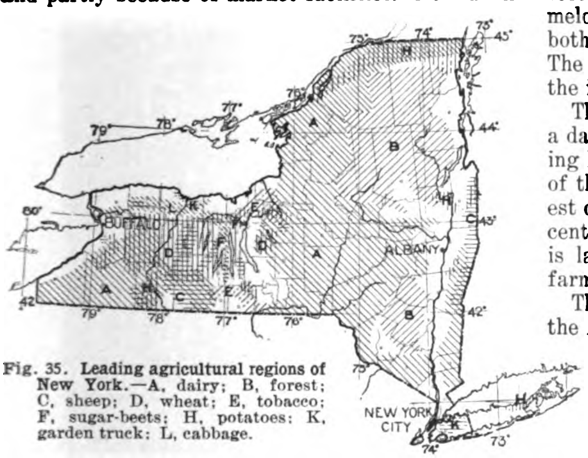


Fig. 35. Leading agricultural regions of New York.—A, dairy; B, forest; C, sheep; D, wheat; E, tobacco; F, sugar-beets; H, potatoes; K, garden truck; L, cabbage.

Long Island is largely a sandy plain, some parts of it fertile, others barren. Geologically it has about the same formation as sections of North Carolina, Virginia, Delaware and Maryland. The more fertile sections are well adapted to potatoes, cucumbers, melons and general garden truck. Poultry-raising, both for eggs and market fowls, is largely practiced. The farming in that section is very intensive and the individual areas are small.

The southeastern part of the state is preëminently a dairy section and is given over largely to producing New York city's milk supply, although in some of the favored valleys horticulture reaches its highest development under the small-area system. The central and upper part of the Hudson river valley is largely given over to milk production, general farming and apple-growing.

The Champlain valley and the plateau north of the Adirondacks is devoted to the growing of potatoes, foods for dairy cattle, and general farming.

To the south of the Mohawk valley large quantities of hay are produced, general farming is conducted and dairying is the specialty. The dairying section makes a belt around the state, reaching from the Catskills through Delaware, Otsego, Ulster and Orange counties in the east, and westward practically across the southern tier of counties to the grape belt on the shores of Lake Erie. Then it follows the Black and Oswego rivers and the banks of the St. Lawrence to the section in the northern part of the state where the same conditions exist.

The greatest apple belt of the state lies along the south shore of Lake Ontario, extending east to the Oswego river and south to the northern limits of the escarpment running across the state from Chautauqua towards the Helderbergs. The counties of Wayne, Monroe, Orleans and Niagara, comprising most of the southern shore of Lake Ontario, are most famed as apple sections, producing enormous quantities for export and home consumption. Peaches are also much grown near the lake. In this apple section many other fruits are grown, and in various localities peaches, grapes and pears are produced in large quantities.

Fig. 36. Farm land in New York.

The Chautauqua grape-growing section lies on the southeastern shore of Lake Erie, extending from the Pennsylvania line almost to Buffalo, and bordering on the east the dairy section already mentioned. Extensive grape areas also lie about Lakes Keuka, Seneca and Canandaigua in the central-western part of the state.

The great bean-producing section of the state lies just south of the apple belt and east of the grape belt, extending to the Genesee river valley. New York is the second state in the production of beans.

Potatoes are grown in large quantities all through the dairy and horticultural sections. Only a small amount of grain is raised, except corn for silage, and this is rapidly increasing. The state stood second in the production of buckwheat at the last census.

Because of good markets and transportation, the crude milk business is bound to increase. The supply for New York city has increased from 4,835,831 forty-quart cans consumed in 1884 to 15,922,436 forty-quart cans consumed in 1904. The demand for milk in the vicinity of the up-state cities, Philadelphia, and cities in New Jersey is also increasing rapidly.

The acreage of alfalfa in the state is constantly increasing, and with it, as a home-grown cattle food, the cost of production of dairy products is bound to decrease, and, consequently, an increase will be made in the output. This means more cows to the acre and more acres devoted to cows.

The demand for home-grown small-fruits in the vicinity of the large cities is always greater than the supply, and the acreage devoted to growing them is bound to enlarge to meet this demand.

The total land area of New York is 30,476,800 acres. Of this, according to the Twelfth Census, 22,648,109 acres are in farms, 15,599,986 acres of which, or 68.9 per cent, are improved. There were then 226,720 farms. The total value of the farm property was $1,069,723,895. The total value of the farm products was $245,270,600. The values of the leading products were: Domestic animals, $120,673,101; dairy products, $55,474,155; hay and forage, $55,237,446; cereals, $34,284,705.

Cornell University, at Ithaca, is the land grant institution of New York, of which the State College of Agriculture and State Veterinary College are a part. The federal Experiment Station is a department of it. There is a well-equipped State Experiment Station at Geneva, opened in 1882. There is a State Department of Agriculture with headquarters at Albany, in charge of a Commissioner of Agriculture, who is appointed by the Governor. This Department has charge of the legal, inspectional and police work of the state as it affects agriculture and agricultural productions, and of the farmers' institutes; it also has supervisory relations with certain work in the College of Agriculture and the State Experiment Station. The state fair is located permanently at Syracuse, and is in charge of the State Fair Commission, consisting of eleven members, of whom the Lieutenant-Governor and Commissioner of Agriculture constitute two, the remaining nine members being appointed by the Governor. The county and local fairs are entitled, under certain conditions, to receive state aid. The leading agricultural societies in the state are as follows: State Grange, State Agricultural Society, State Breeders' Association, State Dairymen's Association, State Fruitgrowers' Association, Western New York Horticultural Society, State Sheep Breeders' Association, State Poultry Society, State Association of Bee-Keepers' Societies, State Association of Agricultural Societies, State Association of Union Agricultural Societies. These various organizations are represented in New York State Association for the Promotion of Agricultural Science and Research.

PENNSYLVANIA. (By *John A. Woodward.*) Perhaps no state in the Union has a wider range of lines, varieties or types of agriculture than Pennsylvania. General farming, dairying, fruit-growing and truck-gardening find their successful followers in all parts of the state, though there is, of course, a degree of specialization due to physiographic and climatic variations.

Corn and the winter cereals are less successful in the northern border counties than in the central or southern parts. In the northern third of the state dairying in all its forms, and fruit-growing, are largely specialized, and oats, hay, buckwheat and tobacco succeed well and are profitable, though more general farming is not neglected, and maple-syrup and sugar add appreciably to the income. The altitude and the rolling character of this section, and the bountiful water-supply, make it a fine pasture-producing area, and dairying has nowhere in the state a larger possible margin of profit.

Corn and wheat probably find their best development south of the center of the state and east of the Alleghany Mountains, though the southwestern section is little, if any, behind.

The great valleys of the central and southern parts of the state are well adapted to general farming, and in these localities may be found its highest development. Lancaster county, on the southern border, is recognized as the richest agricultural county in the Union, and the immense wealth gathered by its farmers is largely to be credited to the tobacco and grain crops and a generally followed system of cattle-feeding.

In the southeastern section, including the half dozen counties surrounding the wonderful market of Philadelphia, dairying and truck-growing are conducted under high pressure, and there is perhaps no other area of equal size in the world where these types of agriculture have reached a higher development, furnished a larger margin of profit, or are conducted by a class of people of higher attainments in all that goes to make life on the farm desirable and beautiful.

The products of Pennsylvania iron-mines, coal-mines and oil-wells are magnificent contributions to the commerce and general well-being of the nation, but it is susceptible of statistical verification that the agriculture is many times greater in value and importance than all of these combined. It is only fair to add, however, that this is largely due to the immense consuming population required for the prosecution of the mining and manufacturing industries.

The transportation facilities are of the very best, and rapidly improving. Of the sixty-seven counties, but a single one is not traversed by railways, and interstate lines give the cheapest of access to the great corn, hay and wheat belts of the West and Middle West. Adding to this fact the wonderfully rapid accession to the non-producing but always consuming population, it seems probable that future developments of the bulk and value of agricultural products will be in the direction of dairying, truck-gardening and other food supplies that bear long and cheap transportation less well than the great staples.

The total land area of Pennsylvania is 28,790,400 acres. Of this, according to the Twelfth Census Report (1900), 19,371,015 acres are in farms, 13,209,183 acres of which, or 68.2 per cent, are improved. There were then 224,248 farms in the state. The total value of the farm property was $1,051,629,173. The total value of the farm products was $207,895,600. The values of the leading products, were: Domestic animals, $97,424,119; hay and forage, $37,514,779; dairy products, $35,860,110; cereals, $50,809,541.

The land grant college is the Pennsylvania State College, located at State College. A State Department of Agriculture has headquarters at Harrisburg, with a secretary and deputy secretary, both appointed by the Governor, as chief officers, the latter having special charge of farmers' institutes. The Department has general charge of the agricultural interests of the state in so far as they are regulated or affected by law. There is also a State Board of Agriculture, the members of which are elected by county agricultural societies. The chief

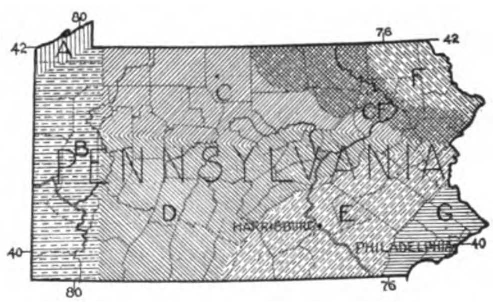


Fig. 37. Main agricultural groups in Pennsylvania.—A, vineyard region; B, wool, grain, grazing; C, forest; D, grazing, grain, fruit; E, dairying, grain, tobacco and fruit; F, dairying; G, trucking and dairying.

organizations whose functions relate to agriculture are as follows: The Department of Forestry, State Agricultural Society, State Horticultural Association, State Grange, State Alliance, Pennsylvania Dairy Union, State Breeders' Association, Pennsylvania Jersey Cattle Club, State Poultry Association, Guernsey Breeders' Association, Pennsylvania Forestry Association, State Bee-Keepers' Association; Pennsylvania Live-Stock Breeders' Association. All these societies and organizations have joined in an alliance under the name of the Allied Agricultural

Organizations of Pennsylvania. The general purpose of this organization is the advancement of agricultural education within the state.

NEW JERSEY. (By *E. B. Voorhees.*) By nature New Jersey is equipped to produce and distribute just the crops demanded by its many markets. From the cranberry bogs and sweet-potato lands of southern New Jersey to the peach country in the north, there is a great diversity of soils, and consequently of crops. There is a strip of red shale soil or clay marl, extending through the center of the state, which enables a majority of farmers to practice mixed-farming. This industry is especially profitable in the central counties. Poultry-raising is a growing industry, predominating in Ocean, Atlantic and Cumberland counties, in the central and southern part, where the soil and climate are ideal. Dairy-farming is very generally and profitably practiced in the western counties, with Philadelphia as a market; in the northern, with New York, Jersey City, Newark and suburbs; and in the eastern, with the ocean resorts as markets.

Fig. 38. New Jersey, showing main agricultural regions. — A, dairying; B, general farming; C, market-gardening; D, potatoes, hay and corn; E, potatoes, tomatoes, sweet-potatoes, melons; F, corn, hay, potatoes, dairying, G, fruit and berries, sweet-potatoes.

The best dairy breeds of cattle are found in Somerset, Burlington and Camden counties, in the central part of the state. Horses, swine and sheep are successfully bred in various sections of the state, the farmers in Hunterdon county, in the northwest, being especially fortunate in securing very early lambs for the New York market.

Next in importance to dairying is market-gardening and trucking; over 1,500 teams daily cross the ferries into Philadelphia alone, while an equal number travel to New York and other large cities. The farmers do their own carting largely, because of the good roads throughout the state. This branch of agriculture predominates in sections near New York and Philadelphia, where good drainage, sandy warm soil, and easy distance from the markets are combined advantages.

Practically all vegetables are grown. Of special crops, potatoes rank among the first. In good years 4,250,000 bushels of Irish potatoes are grown in the state. The sweet-potato thrives in several counties, and 2,500,000 bushels is a good yearly average production. Melons are raised at a profit in the southern counties, and asparagus is depended on in Monmouth and Gloucester counties, in the central and southern part of the state. The Pequest valley in the northwest is noted for its celery and onions.

The canning industry is increasing in importance, large quanties of peas, beans and tomatoes being grown for this purpose in the southern part of the state.

Peaches are the leading fruit, and are grown largely in the northwestern corner. The small-fruits, apples, pears, plums, cherries and quinces prefer the south of the state. Grapes are proving very profitable in Atlantic, Cumberland and Cape May counties, in the south. In 1892, 100,000 gallons of wine were sold from Egg Harbor. Thousands of acres of cranberry bogs are situated in the pine barrens of Ocean and east Burlington counties in the east-central part of the state. Huckleberries grow wild very extensively; in Cumberland county, millions of quarts are picked each year.

The total land area of New Jersey is 4,816,000 acres. Of this, according to the Twelfth Census Report (1900), 2,840,966 acres are in farms, 1,977,042 acres of which, or 69.6 per cent, are improved land. There were then 34,650 farms in the state. The total value of the farm property was $189,533,660. The total value of the farm products was $43,657,529. The values of the leading products were: Domestic animals, $16,269,548; dairy products, $8,436,869; cereals, $6,938,690; vegetables, $8,425,596.

The resources of the state in soil, drainage, climate, season and average rainfall (45-47 inches yearly), the exceptional facilities for travel and communication, together with the growing demand consequent on the growth of the large cities, the improving methods of marketing, and the increasing dissemination of practical knowledge, should make the New Jersey farmer one of the first in the Union.

The land grant college of New Jersey is a part of Rutgers College at New Brunswick; the federal Experiment Station is a department of it. There is a well-equipped State Experiment Station at New Brunswick, founded in 1880. This station has charge of the inspectional and police work of the state as it affects agriculture. There is a State Board of Agriculture, founded in 1872, with headquarters at Trenton, and county boards of agriculture in nineteen counties. This State Board of Agriculture is controlled by a board of directors consisting of two delegates from each of the county boards. The State Board has charge of the farmers' institutes. The State Tuberculosis Commission, located at Trenton, has charge of the bovine tuberculosis in the state, and is governed by a board appointed by the president of the State Board of Agriculture. The leading agricultural societies are the State Horticultural Society and the State Cranberry Association. The State Weather Bureau is located at Atlantic City.

DELAWARE. (By *J. A. Foord.*) Delaware is distinctly an agricultural state, although the manufacturing city of Wilmington is within its borders. According to the Census of 1900, the population of the whole state was 184,735, and of Wilmington

76,508; of the 108,227 people in the state outside of Wilmington, only 17,910 are to be found in the eight towns of more than one thousand inhabitants.

The state is on the shores of Delaware bay and the Atlantic ocean, and geologically most of it is a part of the Atlantic coastal plain. There are three counties, and in a general way the agriculture is divided by county lines. In the northern county, Newcastle, most of the farms are devoted to dairying and general farming; good yields of wheat and corn are the rule and not the exception. The upper third of the county is rolling, the remaining two-thirds practically level; clay or clay loam is the predominating soil type. In 1875 the center of the peach industry of Delaware was in the southern part of this county, but since then it has been gradually moving southward.

Fig. 39. The picking of cranberries. The pickers are "lined off" by the cords stretched across the bog. This fruit is much grown in New Jersey and Massachusetts.

Kent, the central county, has a more sandy soil than Newcastle. About one-half of this county has been surveyed by the agents of the Bureau of Soils of the United States Department of Agriculture; of the area mapped, seventy-five per cent consists of Norfolk loam, Portsmouth sandy loam, and Norfolk silt loam. In this county, fruit-raising and market-gardening, both for immediate shipment and canning, are the principal agricultural industries; dairying is not important and is usually conducted by means of the silo or soiling, as much of the soil is too sandy for either good or permanent pastures. Peaches, apples, plums, pears, grapes, strawberries, raspberries, blackberries, dewberries, asparagus, tomatoes, sweet corn, sweet and Irish potatoes, watermelons, canteloupes and corn are some of the most important products raised for the market. Poultry-raising is also a profitable industry.

Sussex, the southern county, is the largest in area. Corn and wheat have long been staple crops, but are being replaced by small-fruits; of these, strawberries are the most important and are shipped in enormous quantities, with good returns. All the products raised in Kent county will grow in Sussex, but have not been introduced to the same extent. Pine is still growing on some areas, and springs up rapidly whenever land is left uncultivated. The soil varies from a strong loam to a very light sand.

Taken as a whole, the state is level, free from stones, and has a fertile and easily tilled soil. The rainfall is between forty-five and fifty inches annually. The climate is temperate. All the cultivated legumes grow in Delaware and are of great value to the farmer; crimson clover (*Trifolium incarnatum*) has been the most important, but vetches, cowpeas, alfalfa and others are being introduced, and all furnish an easy means of soil enrichment. The large cities of Washington, Baltimore, Philadelphia and New York are all within two hundred miles, and furnish good markets for fruit and produce. Good railroad transportation is furnished, but competition is demanded and may be provided by electric lines in the near future. There are several streams running into Delaware Bay and one into Chesapeake Bay that are navigable for small steamers, and regular communication is maintained with Philadelphia and Baltimore for both freight and passengers.

Large farms of four to six hundred acres are not unknown in Delaware, but the average area of the farms is 110 acres. As in other states, the labor question is not yet solved, and this is probably one of the reasons why only 49.7 per cent of the farms are operated by their owners; of the remaining number, 42.5 per cent are conducted by share tenants and 7.8 per cent by those who pay a cash rental. This ratio is undoubtedly changing. Farms are being divided and more intensive methods adopted. The State Board of Agriculture is also a Bureau of Immigration, and considerable information has been distributed, with the result that farmers from other states and Canada are settling in Delaware. If present events are an indication of future happenings, Delaware will continue to furnish the fruits of the temperate zone to the inhabitants of the large cities.

The total land area of Delaware is 1,254,400 acres. Of this, according to the Twelfth Census Report (1900), 1,066,228 acres are in farms, 754,010 acres of which, or 70.7 per cent, are improved land. There were then 9,687 farms in the state. The total value of the farm property was $40,697,654. The total value of the farm products was $9,290,777. The values of the leading products were: Domestic animals, $3,733,335; dairy products, $1,092,807; cereals, $3,032,513; vegetables, $1,144,221; fruit, $756,449. These figures need explanation. They are based on the crop of 1899. With the exception of 1890, the peach crop in Delaware in 1899 was the poorest on record since 1866. In 1899 there were only 3,157 baskets of peaches carried by the Delaware division of the Pennsylvania railroad, while the shipments over the same road for the three succeeding years were as follows: 1900, 2,634,203 baskets; 1901, 1,111,582 baskets; 1902, 1,772,223 baskets. These figures comprise shipments from the entire peninsula, but do not include shipments by water nor fruit used by canneries. The average fruit crop of Delaware is worth nearly two million dollars.

Delaware College, at Newark, is the land grant institution of the state; the professor of chemistry is ex-officio State Chemist, and has charge of the inspection of fertilizers. The federal Experiment Station is a department of the college, and the State Board of Health laboratory is located there, although the latter is under an independent and entirely different board of control. The State College for Colored Students is at Dover. The State Board of Agriculture consists of three members appointed by the Governor, and a corresponding secretary, who supervises the work. The Board has an office in Dover, and, in addition to its other duties, has charge of nursery inspection and the control of contagious animal diseases. An annual fair is held under the auspices of the State Grange. The Peninsula Horticultural Society holds its meetings on alternate years in Delaware and Maryland, and receives small appropriations from each of these states. Farmers' institutes are under the direction of county organizations that may call on the state director for assistance and suggestion.

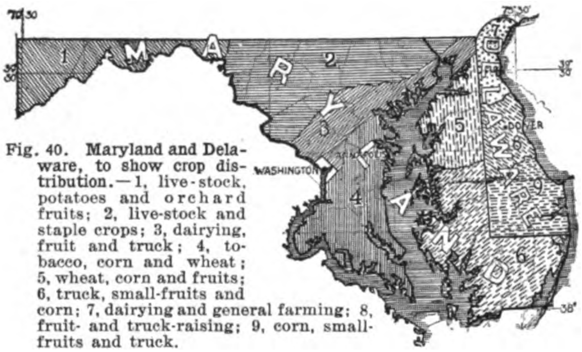


Fig. 40. Maryland and Delaware, to show crop distribution.—1, live-stock, potatoes and orchard fruits; 2, live-stock and staple crops; 3, dairying, fruit and truck; 4, tobacco, corn and wheat; 5, wheat, corn and fruits; 6, truck, small-fruits and corn; 7, dairying and general farming; 8, fruit- and truck-raising; 9, corn, small-fruits and truck.

MARYLAND. (By *H. J. Patterson.*) The agriculture of Maryland is conducted on many different kinds of soils, and under a wide range of climatic conditions, owing to the considerable variations that exist between the tide-water lands at sea-level in the east and the mountain lands over 200 miles to the west with an elevation of as much as 3,000 feet.

For the purpose of agricultural classification Maryland is naturally divided into four parts, viz.: eastern, southern, north-central and western Maryland.

Eastern Maryland, known as the "Eastern Shore," lying between Chesapeake Bay and the ocean, is uniformly level, with fairly good roads, and well watered from tidal estuaries or creeks. This section has a long growing season and short, mild winters. The soil is early. The transportation facilities by water and rail are very good. The main crops of this section are the staples, with corn and wheat predominating, peaches, early vegetables, small-fruits and canning crops.

The soil and climate of southern Maryland are well adapted to tobacco-growing, and the best tobacco in the state is grown here. Much land is also devoted to the staple crops and to vegetables and small-fruits. Dairy-farming is profitable, especially near Washington. The transportation facilities by water and rail are good.

The soil of north-central Maryland is mostly stiff clay and clay loam, generally underlaid with rock and well drained. The valleys are usually very fertile. Mixed husbandry largely predominates. Dairying, trucking and canning are very prominent.

Western Maryland is chiefly mountainous and coal-mining is an important industry. The land is well adapted to grazing and stock-raising, and these should be more largely pursued than at present. Apples do well here. Oats, buckwheat and potatoes are the principal crops. Garrett county produces annually about 250,000 pounds of maple-sugar, and almost every farm has a chestnut grove, which adds considerable to the revenue. Washington and Frederick counties abound in productive land, and the best farms in the state are found in this division. The land is mostly of limestone origin.

Maryland stands first in the amount of tomatoes and peas canned, and fourth in corn. Nearly one-third of the total amount of tomatoes and one-fourth of the total amount of peas canned in the United States are packed here. All classes of vegetables and fruits are packed to some extent, and oysters and crabs extensively. Baltimore, Washington and Philadelphia give good markets for all kinds of products, especially milk and cream. The state was famous for its peaches until these were wiped out on the Eastern Shore by peach yellows, but the industry is now again on the increase. Pears, plums and cherries are grown extensively in many parts of the state. Apples grow well in all parts. Chestnuts, shellbarks, English walnuts, filberts and pecans do well in many parts of the state. Small-fruits are also extensively grown, the strawberry being the most important, though raspberries and blackberries also occupy a prominent place. Trucking will always be one of the great specialties of the state.

Poultry, hogs and sheep are probably the most profitable live-stock. Hogs are raised in the dairy and mixed husbandry sections of the state, and are a paying industry. Sheep-raising, especially the raising of early lambs, is a remunerative business, and should be extended.

The total land area of Maryland is 6,310,400 acres. Of this, according to the Twelfth Census Report (1900), 5,170,075 acres are in farms, 3,516,352 acres of which, or 68 per cent, are improved land. There were then 46,012 farms in the state. The total value of the farm property was $204,645,407. The total value of the farm products was $43,823,419. The values of the leading products were: Domestic animals, $19,636,844; dairy products, $5,228,698; cereals, $14,505,992; vegetables, $5,315,732.

The land grant institution of Maryland is designated as the Maryland Agricultural College, at College Park. The Experiment Station is a department of it. The State Department of Farmers' Institutes, the State Horticultural Department, and the State Fertilizer and Cattle Food Control are all departments of the Agricultural College. There is no state department or commissioner of agriculture. The leading agricultural societies are as follows: The Maryland Farmers' League, which is made up of delegates from all the farmers' organizations in the state; the State Horticultural Society and the Peninsula Horticultural Society. The state fair has no permanent home, but acts in conjunction with the county fairs, taking them in rotation. The State Bureau of Industrial Statistics, at Baltimore, collects information on agriculture, and the State Bureau of Immigration aims to develop the rural sections and settle persons on the farm lands.

VIRGINIA. (By *H. L. Price.*) Virginia consists of six natural divisions, each having its own peculiar soil types, and, to a less extent, its characteristic climate.

Beginning on the northwestern border of the state, the division known as Appalachia consists chiefly of high mountain ranges and deep, narrow valleys. This section not only abounds in minerals, but its soils are well adapted to stock-raising, general farming and fruit-growing. Lack of transportation facilities to some extent prevents an extensive development of the latter two industries, hence we find stock-raising the chief type of farming. Bluegrass grows everywhere and, on the better types of soil, export cattle of the finest grade are finished on grass.

The next section is the great valley of Virginia, comprising the Shenandoah and other valleys. Here the soil is mostly limestone clay, and grain-growing becomes the most important industry. Grazing and trucking are followed in the southwest, while fruit-growing has become of paramount importance on certain poorer soil types of Augusta and Frederick counties. Betetourt, which lies in the middle part of this section, has long been noted for its canning industry.

The Blue Ridge parallels the great valley on the southeast, and comprises a narrow mountainous strip of territory which is not especially adapted to farming except in the mountain passes and in the southern part, where this range widens out into a broad plateau, and includes the counties of Floyd, Carroll and Grayson. Here the soil is well adapted to general agriculture and to fruit-growing, but transportation facilities are very poor.

To the east lies the piedmont section, which includes the foothills of the Blue Ridge; this comprises a narrow strip of territory extending from the northern to the southern borders of the state. Grain-farming and fruit-growing are the principal industries. Stock-raising, especially the raising of fine horses, and dairying are practiced in certain localities, but the chief difficulty is a soil not adapted to grass. This does not apply in Rappahannock and Loudoun counties, where grasses thrive with little attention.

The fifth section is known as middle Virginia. Geologically this is the oldest section of the state, and the soils are generally poor. Tobacco is the main crop, while corn and wheat succeed on the best types of soil.

Lastly, tidewater is the largest natural division of the state, and comprises some several thousand square miles of territory. This is preëminently the trucking area of the state. The soil is light and responsive and the climate mild, and the entire area is destined to become one vast garden in the near future. General crops are not extensively grown, the chief products being sweet-potatoes and various other truck crops.

On the whole, the state is rich in natural resources, and the future wealth is chiefly dependent on the development of its agriculture. Transportation facilities are good. Besides the several railways traversing the state, an immense water-front is offered in bays, estuaries and navigable rivers. Fruit-growing is developing at a rapid pace in certain sections and is destined to become one of the principal phases of the agriculture of the state.

The total land area of Virginia is 25,680,000 acres. Of this, according to the Twelfth Census Report (1900), 19,907,883 acres are in farms, 10,094,805 acres of which, or 50.7 per cent, are improved land. There were then 167,886 farms in the state.

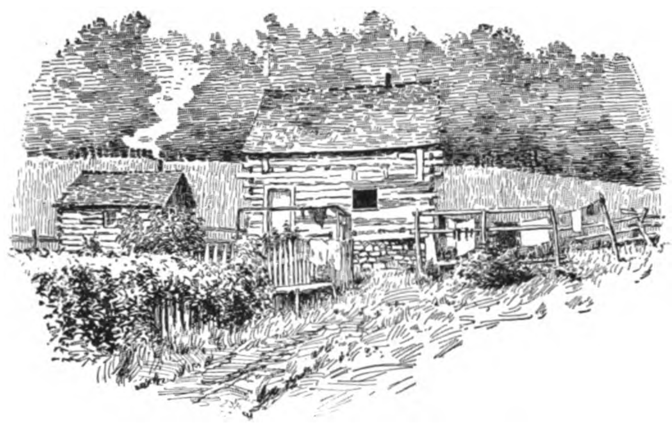


Fig. 41. A backwoods home in the piedmont country.

The total value of the farm property was $323,515,977. The total value of the farm products was $86,548,545. The values of the leading products were: Domestic animals, $39,831,552; hay and forage, $7,670,082; cereals, $23,759,479; vegetables, $9,083,274.

The land grant college of Virginia, known as the Virginia Polytechnic Institute, is located at Blacksburg. The federal Experiment Station is a department of it. The inspectional work for insects and plant diseases is under the charge of the State Crop Pest Commission. This work is supported by state funds, but is under the direction of the Virginia Polytechnic Institute Board. A State Test Farm has been recently established at Saxe, under the control of the State Board of Agriculture. This Board is appointed by the Governor, while the Commissioner of Agriculture, who acts as its secretary, is elected by the people. The headquarters of the State Department of Agriculture is at Richmond. It has charge of such work as ordinarily falls to an agricultural department; also, the inspectional work relating to fertilizers. The State Board of Agriculture and the Experiment Station, at Blacksburg, coöperate in the farmers' institute work. The state fair has been recently reorganized and will be permanently located at Richmond. The leading agricultural societies are the Virginia State Horticultural Society and the State Farmers' Institute. The latter society has permanent headquarters in the city of Roanoke.

4. SOUTHERN EAST-CENTRAL OR APPALACHIAN STATES

WEST VIRGINIA. (By *Horace Atwood.*) The state of West Virginia, taken as a whole, is mountainous or hilly, and is somewhat sparsely settled. It is traversed from northeast to southwest by the Appalachians, and this mountainous region comprises about two-fifths of the area of the state.

The agriculture in the mountains is confined mainly to the raising of cattle and sheep, but on some of the ridges apples and peaches have been found to grow remarkably well. As soon as transportation facilities are improved, this will undoubtedly become one of the great fruit-producing sections of the United States. A large part of the mountainous area is still heavily timbered.

The remainder of the state, although even this is somewhat hilly and broken, is devoted to general agriculture. Corn, wheat, oats, rye, buckwheat, potatoes and tobacco are raised, and a considerable amount of live-stock is kept. The bottoms along the rivers are very fertile, but the soil of the uplands is thin in many sections, and is better adapted to grazing than to the production of crops. Over much of the state, and especially on the limestone soils, blue-grass grows to perfection, and many export cattle are shipped directly from the pastures. Dairying is not much engaged in, although it would seem that the conditions are particularly favorable for the development of this branch of agriculture. The climate is mild and agreeable, and the precipitation is abundant and well distributed.

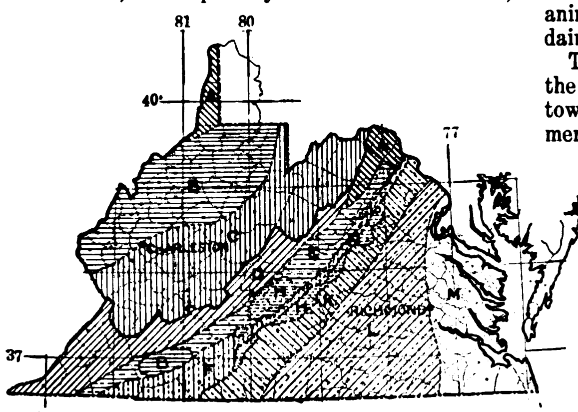


Fig. 42. Distribution of agriculture in the Virginias. A, fruit and general agriculture; B, grazing and general agriculture; B, in Virginia, also cabbage; C, D (mountainous), grazing or stock-growing the chief industries; E, grain-growing; F, general agriculture; H, fruit; K, grain and fruit; L, tobacco, corn, wheat; M, truck; N, fruit in mountain gaps.

West Virginia is one of the chief coal-producing states of the country, and the numerous busy mining towns afford ready markets for farm produce. Dairy and poultry products are particularly high in price, and large quantities of butter, cheese, eggs and poultry are shipped in from other states to supply the demand.

The mining and manufacturing towns are increasing rapidly in size and number, and the agricultural development has failed to keep pace with the increased demands for farm products. This condition will soon be changed, as local consumption is stimulating production, and a more intensive and diversified agriculture will result throughout the state.

The total land area of West Virginia is 15,772,800 acres. Of this, according to the Twelfth Census Report (1900), 10,654,513 acres are in farms, 5,498,981 acres of which, or 51.6 per cent, are improved land. There were then 92,874 farms in the state. The total value of the farm property was $203,907,349. The total value of the farm products was $44,768,979. The values of the leading products were: Domestic animals, $29,231,832; hay and forage, $5,517,073; dairy products, $5,088,153; cereals, $11,571,334.

The land grant institution of West Virginia is the West Virginia University, located at Morgantown. The federal Experiment Station is a department of it. There is a State Board of Agriculture, with headquarters at Charleston, whose duty it is to devise means of advancing the agricultural interests of the state, to promote the holding of farmers' institutes, to encourage the organization of associations in the interest of agriculture, and to have charge of the contagious diseases of animals. The Experiment Station has charge of the inspection of fertilizers and nurseries. The leading agricultural organizations of the state are as follows: West Virginia State Horticultural Society, West Virginia State Poultry Association, West Virginia State Dairy Association, West Virginia State Wool-Growers' and Sheep-Breeders' Association. There is no state fair, but the Horticultural Society, the Poultry Association and the Dairy Association hold exhibitions in connection with the annual meetings.

KENTUCKY. (By *J. N. Harper.*) In Kentucky there are five regions, each differing in soil, and to some extent in climate; namely, the mountainous section of the east, the low foot-hills of the south, the high plateau and rolling hills of the central and northern part, the alluvial soils along the Ohio and Green rivers, and the low, clay lands of the west and south. The different soil types and climatic conditions of these five regions are the chief factors in controlling the distribution of agricultural products.

In the mountainous region of the east and in the low foot-hills of the south there are many types of soils, varying from sandstone to poor shaly clays. The bottom-lands are highly productive, timothy, red-top, oats and maize being grown successfully. But the agricultural resources of these regions are not developed; the main industry is the lumbering of hard woods, and mining in some parts.

The soil of the gentle rolling hills of the central and northern part of the state, formed by the disintegration of silurian limestone, consists of a fine loam with a clay subsoil. This region is known as the "blue-grass region" of Kentucky. In this region nine-tenths of the hemp grown in the United States and nearly all of the White Burley type of tobacco are produced. Corn, wheat, oats, clover, timothy, sorghum, potatoes, cowpeas, and all kinds of vegetables and small-fruits are grown. It is by a judicious rotation of crops in connection with the use of the land for pasturage that the wonderful productiveness of the soil is maintained undiminished. This fact has made the region for decades famous the world over for its fine horses and cattle.

The alluvial soils of the western-central part of the state, along the Ohio and Green rivers, are entirely different from the soil of the blue-grass region. This section produces millions of pounds of the dark export tobacco, known as the Green River tobacco, and is well suited to the growing of maize, various grasses and peas. Truck-farming is extensively conducted in the vicinity of Louisville and Owensboro, onions, cabbages, potatoes and beans being especially productive.

The southwestern division consists of red clay lands, which are productive. The chief crops are dark export tobacco, corn, wheat, clovers, peas, potatoes, timothy, oats, orchard-grass, red-top and other grasses.

By its many navigable rivers and different railway systems nearly all parts of Kentucky, except the mountainous region of the east, are well supplied with facilities for marketing crops. The agricultural conditions of the future will be little influenced by the building of new railroads, except that there are some soils, well adapted to trucking, that might be profitably used for this line of agriculture if better transportation facilities could be had.

Kentucky is destined to lead the world some day in animal husbandry. Its soil and climatic conditions are ideal for the raising of horses, mules and beef- and dairy-cattle.

The total land area of Kentucky is 25,600,000 acres. Of this, according to the Twelfth Census Report (1900), 21,979,422 acres are in farms, 13,741,968 acres of which, or 62.5 per cent, are improved land. There were then 234,667 farms in the state. The total value of the farm property was $471,045,856. The total value of the farm products was

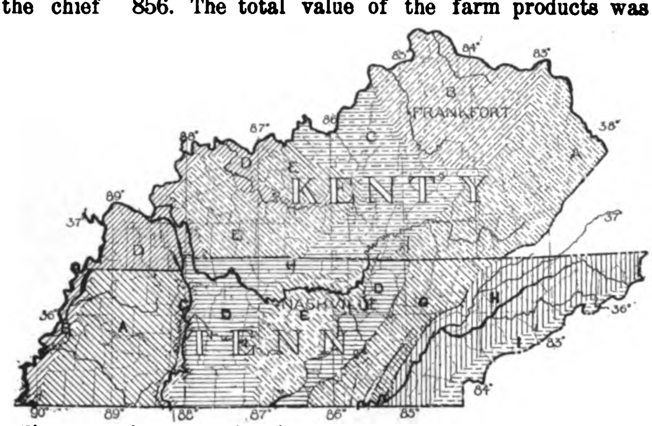


Fig. 43. Agricultural regions in Kentucky and Tennessee. *Kentucky*—A (mountainous section, undeveloped), lumbering; B (blue-grass region), live-stock, hay, grain, hemp and vegetables; C (low foothills), hay and grain in the bottom lands; D (low lands), tobacco, grain and hay; E (alluvial soils), tobacco and trucking. *Tennessee*—A (slope of west Tennessee), silt soils adapted to wide range of crops; B (Mississippi bottoms), adapted to corn, cotton, wheat, alfalfa, etc.; C (western valley), river lands, are very fertile; D (highland rim), red soils adapted to general farming, gray soils less fertile, extensive phosphate deposits; E (central basin), clay loams, suited to general farming abound; G (Cumberland plateau), timber and cattle ranges, orcharding, grape-growing, etc., also coal; H (valley of East Tennessee), general farming, ridges adapted to orcharding; I (Unaka range, eastern boundary of Tennessee), timber and some grazing for stock, scattered fertile valleys.

$123,266,785. The values of the leading products were: Domestic animals, $70,488,187; dairy products, $9,985,540; cereals, $39,692,771; tobacco, $18,541,982.

The land grant college is at Lexington, known as the Agricultural and Mechanical College of Kentucky. The federal Experiment Station is a department of it. There is a State Department of Agriculture, with headquarters at Frankfort, in charge of the Commissioner of Agriculture, who is elected by the people. This Department has charge of the state farmers' institute work; and it collects statistics of agricultural conditions at stated intervals during the year. It also has charge of the labor statistics. A state fair has been held for the last four years under the management of the State Live-Stock Breeders' Association. The legislature of 1906 passed an act providing for a permanent state fair, with location to be decided. The leading agricultural and horticultural societies in the state are the State Horticultural Society and the Live-Stock Breeders' Association.

TENNESSEE. (By *Chas. A Mooers.*) Soil and climatic conditions of Tennessee are unusually favorable to the profitable production of a wide range of crops. Corn, wheat, grass and forage crops are staples in practically every county in the state. Cotton is a staple crop in about one-half of the counties. Tobacco-growing could be extended over an area equally large, and is of importance over about one-fourth of the state. Clarksville, in the northwest, and Greeneville, in the eastern part, are the centers of tobacco production. Peanuts, millet for seed, and broom-corn are general farm crops in some localities. Trucking and small-fruit-growing have assumed much importance in west Tennessee. Early Irish potatoes and strawberries for the northern markets are grown in other sections. Commercial peach- and apple-orcharding are not well developed. Extensive fruit- and ornamental-tree nurseries are maintained in various parts of the state.

Geographical position, soil, climate and water, which is plentifully supplied in springs and streams the state over, are all favorable to stock husbandry. Good horses and mules, beef animals, hogs and sheep are all raised, and these industries will bear extension. Dairy-farming is being developed. Poultry-raising has received a marked impetus in the last few years.

There are eight well-defined agricultural sections, due to variations in soil texture and fertility and to altitude. These areas may be described as follows (the letters designating the areas on the map):

I. Unaka range. The area of this section is about 2,000 square miles. It furnishes timber and some grazing for stock, and there are scattered fertile valleys.

H. Valley of east Tennessee. This covers an area of about 9,200 square miles. Clay soils, well suited to general farming, predominate. The ridges are adapted to orcharding.

G. Cumberland plateau. Thin, sandy and clayey soils cover this section, which is valuable for timber and cattle ranges; also for orcharding and grape-growing. This is the coal area of the state.

D. Highland rim. This section surrounds the central basin and has an area of about 9,300 square miles. The red soils are well adapted to general farming. The gray soils are less fertile. The phosphate deposits are extensive.

E. Central basin. This has an area of about 5,500 square miles. It is the richest agricultural section and is characterized by blue-grass and stock. Durable clay loams, well suited to general farming, abound. Rich phosphate beds are mined.

C. The western valley. This has an area of some 1,200 square miles. The river lands are very fertile.

A. Slope of west Tennessee. The area is about 8,850 square miles. Silt soils, adapted to a wide range of crops, characterize this section, which leads in the production of cotton.

B. Mississippi bottoms. This area is about 950 square miles. The land is of almost inexhaustible fertility, adapted to corn, cotton, wheat, alfalfa.

The rivers furnish about 1,200 miles of navigable water, which gives important means of transportation to more than one-third of the counties. Five railroad systems have a total of 3,161 miles of road in the state, so that out of the ninety-six counties only sixteen are without a railroad and only eight without either steamboat or railroad transportation. The counties containing the larger cities and towns are well supplied with macadamized roads.

The home demands take practically all the hay and forage and the larger part of the corn and wheat. Cotton, tobacco, peanuts, trucking crops and nursery stock are extensively shipped out of the state, as are also various classes of live-stock and poultry. The future agricultural development promises to be great in all kinds of live-stock farming, especially dairying, in trucking, and in fruit- and fruit-tree-growing.

The total land area of Tennessee is 26,720,000 acres. Of this, according to the Twelfth Census (1900), 20,342,058 acres are in farms, 10,245,950 acres of which, or 50.4 per cent, are improved. There were 224,623 farms in the state. The total value of the farm property was $341,202,025. The total value of the farm products was $106,166,440. The values of the leading products were: Domestic animals, $58,043,895; dairy products, $8,028,466; cereals, $36,914,592; cotton, $9,166,688.

The University of Tennessee, located at Knoxville, is the recipient of the land grant act, and the federal Experiment Station is a department of it. Nashville is the headquarters of the State Department of Agriculture, which is in charge of a Commissioner of Agriculture appointed by the Governor. This Department has direction of the inspectional and police work of the state as respects agriculture, and of the farmers' institutes. A state fair has recently been established, with headquarters at Nashville. The leading agricultural societies in the state are: The East Tennessee Farmers' Convention, the Middle Tennessee Division Institute, the West Tennessee Division Institute and the Tennessee Horticultural Society.

5. ATLANTIC COTTON STATES

NORTH CAROLINA. (By *W. A. Withers.*) About one-fifth of the North Carolina farms are grain and hay farms, nearly one-fifth are cotton farms, about one-eighth live-stock, one-twelfth tobacco, a little over one per cent vegetable farms, and one per cent fruit farms. Over one-third of the farms of the state cannot be classed as special.

The state is divided into three sections, which differ very much from each other, viz.: The western or mountainous section, the middle or piedmont section, and the eastern or coastal plain section. The mountainous section has an average elevation of 4,000 feet, although it drops somewhat at the northern and southern extremities. The area of the section is about 6,000 square miles. This plateau contains the largest masses and the highest summits of the Appalachian system. It includes Mount Mitchell, the highest peak on the eastern half of the continent, with an elevation of 6,711 feet, forty-two other peaks of over 6,000 feet, and twice that number which approximate this altitude. In the mountainous section are many fertile valleys, coves and slopes, which are well suited to corn-, fruit- and stock-raising. The cabbage and Irish potato reach their best development here. The mean annual temperature is about fifty-six degrees and the rainfall fifty-three inches. In it are various belts which are untouched by frost.

The central or piedmont section comprises about one-half of the area of the state. This section is rich in water-power, and the cotton factories and mining interests are more developed than elsewhere. Here cotton and tobacco are grown most extensively, and grain, hay and fruit find congenial conditions. The mean annual temperature is sixty degrees and the rainfall fifty inches.

The eastern section of the state has been under cultivation in some parts for over two hundred years. In the early days the grape grew here luxuriantly. The upland soil of the eastern section is for the most part a sandy loam overlying clay, with an increasing amount of organic matter as the coast is approached. This section is well suited to cotton, corn, peanuts and Irish and sweet-potatoes. Tobacco culture has recently been introduced very successfully. Rice and sugar-cane are grown with profit in the southern part. Grass grows well, and the conditions are very favorable for the development of the live-stock industries. Here the mean annual temperature is sixty-one degrees and the rainfall fifty-five inches.

North Carolina has no large cities. The manufacturing centers offer good markets for the farm products. The transportation facilities are good, having the ocean and several navigable streams in the east, and three large railroad systems with their branches and smaller connecting lines throughout the state. In many sections there are modern and well-constructed earth roads.

The agricultural development is along the lines of stock-raising, trucking, fruit-growing, diversified farming and the introduction of improved agricultural implements.

The total land area of North Carolina is 31,091,200 acres. Of this, according to the Twelfth Census Report (1900), 22,749,356 acres are in farms, 8,327,106 acres of which, or 36.6 per cent, are improved land. There were then 224,637 farms in the state. The total value of the farm property was $233,834,693. The total value of the farm products was $89,309,638. The values of the leading products were: Domestic animals, $28,242,147; cotton, $17,987,723; cereals, $22,082,175; tobacco, $8,038,691.

The federal appropriation for the establishment of land grant colleges has been divided between the white and the black races in proportion to population. The institution for the whites is at Raleigh, and was opened in 1889. The institution for the colored race is in Greensboro, in the north-central part of the state, and was established in 1891. The federal Experiment Station is a department of the Agricultural College at Raleigh. There is a State Department of Agriculture, with headquarters at Raleigh, in charge of the Commissioner of Agriculture, who is elected by the people. The college for the whites, the Experiment Station, and the Department of Agriculture are under the control of the State Board of Agriculture, consisting of ten members appointed by the Governor and confirmed by the senate, and of the Commissioner of Agriculture, who is ex-officio chairman of the Board. The Agricultural College for the colored race at Greensboro is under the management of separate Boards of Trustees similarly appointed. The State Department of Agriculture has charge of the legal, inspectional and police work of the state as it affects agriculture; of the farmers' institutes, and of the test farms which have been established in various sections. The state fair is permanently located at Raleigh, and is under the control of the North Carolina Agricultural Society. Leading agricultural societies are: The State Horticultural Society, the Cotton-Growers' Association, Tobacco-Growers' Association, Truckers' Association, Nature Study Society, Commission for Controlling Crop Pests, Dairymen's Association, Poultry Association, State Farmers' Alliance, the State Highway Commissioners.

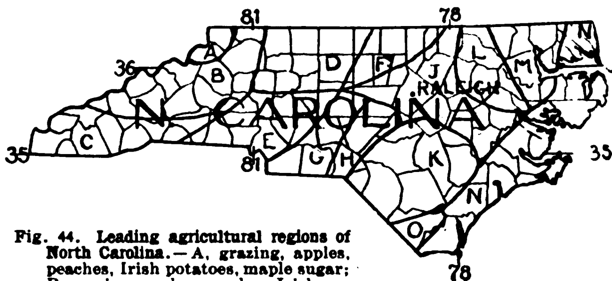


Fig. 44. Leading agricultural regions of North Carolina.—A, grazing, apples, peaches, Irish potatoes, maple sugar; B, grazing, apples, peaches, Irish potatoes; C, grazing; D, grazing, apples, Irish potatoes, small grain, tobacco; E, cotton, grazing, small grain; F, tobacco; G, cotton; H, cotton, early peaches; J, cotton, tobacco, sweet-potatoes; K, cotton, sweet-potatoes, strawberries; L, cotton, tobacco, sweet-potntoes, peanuts; M, cotton, peanuts; N, rice; O, sugar-cane.

SOUTH CAROLINA. (By *C. L. Newman.*) The predominating type of agriculture in South Carolina is that of mixed-farming. Cotton holds the position of greatest importance, and is grown throughout the state with the exception of the upper edges of the two extreme northwest counties (Oconee and Pickens). Corn is grown throughout the state for home consumption, very little being marketed outside the state.

The climatic and physiographic features of the state have a marked effect on agriculture, since the elevation varies from sea-level to the mountains in the northwest, the highest of which (Mt. Pinnacle) reaches an altitude of 3,424 feet. This difference in elevation, in association with proximity to sea and variation of soil, gives a regular gradation of conditions from sea to mountains, dividing the state into four sections: (A) The tide-water area, where rice, sea-island cotton and truck-gardening are the predominating types, each, in certain localities, being specialized; it also produces sweet-potatoes and sugar-cane. (B) The coastal plain section, extending from the tide-water section to a line running from Augusta, Georgia, to Columbia, and thence through Lancaster and Chesterfield counties. This section produces, in addition to cotton and corn, the principal crops, tobacco, oats, cowpeas, sorghum, potatoes, strawberries, lettuce, asparagus, cucumbers, peas, beans, radishes and cabbages. Trucking for northern markets has assumed important proportions and is becoming a prominent industry. (C) The third section shades from the coastal plain into the foot-hills, becoming somewhat rugged northward, the line of demarcation being more geological than agricultural; and it is separated from the preceding section by the tertiary coast-line. Cotton is the chief product, but corn is extensively grown and the trucking interests are of some consequence, strawberries, cantaloupes, watermelons and peaches being grown in certain parts, particularly along the southern border of this area between Columbia and Augusta, Georgia. Extensive peach plantings are being made in the extreme northwestern part of the section. In this upper third of the state, small grain is grown. In the northeastern part, tobacco is extensively grown, and some attention has been given tea culture. (D) The fourth section is mountainous and sparsely settled. On the tillable land, cabbages and Irish potatoes do well and apples of the finest quality and appearance are produced to a limited extent. This area will some day produce many apples.

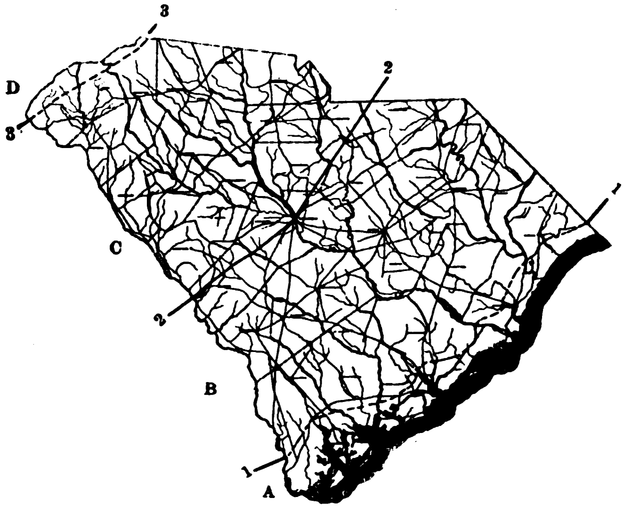


Fig. 45. South Carolina.—A (tide-water region, below 1), given to sea-island cotton and trucking; B (coastal plain, below 2), cotton, corn and general crops; C (foot-hill or piedmont region, below 3), cotton, corn, fruit, small grain; D (mountain region), farming restricted.

Distance from market and unsatisfactory railroad rates have confined the bulk of trucking interests near the coast; but, as better railroad facilities develop, trucking will become a very important industry. Too little attention has been paid to stock-raising and diversification, but there is a strong tendency in both directions and to an increase in the areas devoted to truck crops and fruit. The climatic and soil conditions are excellent for these purposes, and when the value of Bermuda grass for hay is better appreciated and the coarser forage plants better understood, the live-stock industries will become an important type of agriculture. The future development will be in the direction of diversification and specialization in crops other than cotton.

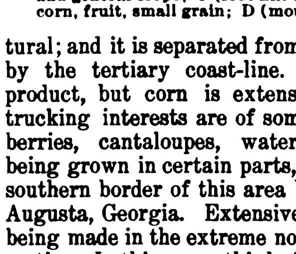


Fig. 46. A sea-island negro cabin.

The total land area of South Carolina is 19,308,800 acres. Of this, according to the Twelfth Census Report (1900), 13,985,014 acres are in farms, 5,775,741 acres of which, or 41.3 per cent, are improved land. There were then 155,355 farms in the state. The total value of the farm property was $153,591,159. The total value of the farm products was $68,266,912. The values of the leading products were: Domestic animals, $19,167,229; cotton, $34,563,553; cereals, $12,722,415; vegetables, $4,064,847.

The land grant college is designated officially as The Clemson Agricultural College of South Carolina. The federal Experiment Station is a department of it; a branch station is located near Charleston and is known as The Coast Branch Experiment Station. The college has control of fertilizer inspection, veterinary and sanitary work and entomological state inspection. There is a State Agricultural and Mechanical Society, with head-quarters at Columbia. The State Fair Association is organized and conducted under the auspices of this society on permanent grounds. The Department of Agriculture, Commerce and Immigration, with headquarters at Columbia, is in charge of the Commissioner of Agriculture appointed by the Governor. There is a South Carolina Live-Stock Association. The director of farmers' institutes is also director of the Experiment Station and of the agricultural department of Clemson College.

GEORGIA. (By *H. N. Starnes.*) While Georgia is essentially a cotton state, ranking next to Texas in total output, its peculiar topography renders possible a remarkably diversified agriculture. Latitude and elevation combine to create an extensive climatic range, since the land rises gradually from the coast to the Tennessee line, where some of the mountains attain an altitude of about 5,000 feet. This exaggerates the four and one-half degrees of latitude covered by the state into probably double that number, and gives rise to the following crop zones or belts:

1. The rice belt, confined to the narrow tide-water strip of the coastal plain. The rice industry is declining in Georgia, however, and is being partially superseded by trucking.

2. The sea-island cotton belt, a zone extending inland from the coast from eighty to one hundred and thirty miles in breadth. Its northwestern limit is being steadily pushed farther inland and will soon be coterminous with the yellow (or long-leaf) pine region. The soil of this area is principally gray, light, and easily worked, and is underlaid by the yellow tertiary sands. Commercial melon-growing is confined chiefly to this belt.

3. The upland cotton belt, covering the remainder

of the state, with the exception of a few northern counties. Upland, or short-staple, cotton is also grown throughout the greater part of the sea-island belt, but is being gradually displaced by the latter.

4. The mountain region, in the northeastern and northwestern corners of the state,—too elevated for cotton—its climate approximating that of the North Atlantic States. This area grows only corn, cereals, grasses and fruits.

North of an escarpment extending across the state from Augusta via Macon to Columbus the soil is mainly thin and red, with a stiff red clay subsoil, and a hardwood growth. Southward it is gray and sandy, with the prevailing growth yellow pine. This line may be regarded as the present approximate lower limit of wheat production and the upper limit of sugar-cane, although both crops considerably overlap. Corn and oats are largely grown in all of the crop zones, but are consumed on the farm, not exported.

The annual rainfall is comparatively uniform, and will average forty-nine inches for the state as a whole, though heavier in the mountains and on the coast.

In the relative order of their value, the agricultural products of Georgia (excluding live-stock) are: cotton, corn, peaches, sweet-potatoes, hay, watermelons, cowpeas, wheat, oats peanuts, syrup and rice.

Trucking and fruit interests are rapidly expanding. Georgia is now the largest peach-growing

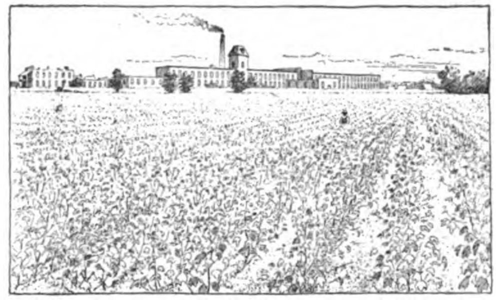


Fig. 48. From field to factory.—The juxtaposition of cotton fields to cotton factory in the New South.

state. Tobacco is raised only for home consumption, except in the extreme southwestern corner.

Stock-raising and dairying are annually receiving more attention because of the cheap and reliable summer pasturage afforded by Bermuda grass. Manufacturing, principally textiles, is largely on the increase, and well distributed over the state. Georgia stands first in the production of naval stores.

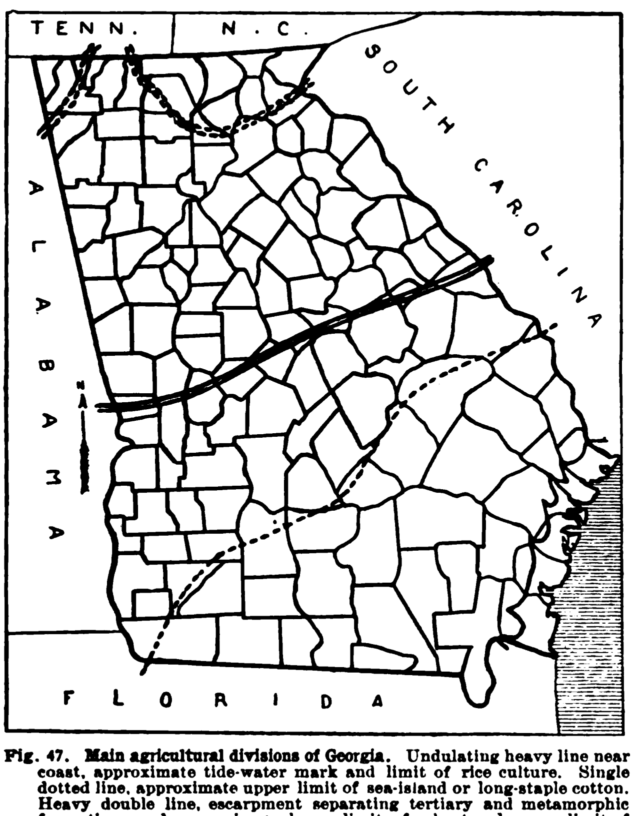


Fig. 47. Main agricultural divisions of Georgia. Undulating heavy line near coast, approximate tide-water mark and limit of rice culture. Single dotted line, approximate upper limit of sea-island or long-staple cotton. Heavy double line, escarpment separating tertiary and metamorphic formations and approximate lower limit of wheat and upper limit of sugar-cane. Double dotted line, northern limit of upland, or short-staple cotton.

Transportation facilities are already ample and new lines are being constructed as rapidly as needed; concentrating at Savannah, the chief South Atlantic port, a convenient outlet is there found for an enormous export trade in cotton, lumber and naval stores.

Georgia will continue to be a cotton state, with increasing attention paid to the mineral, manufacturing and fruit-growing interests.

The total land area of Georgia is 37,747,200 acres. Of this, according to the Twelfth Census Report (1900), 26,392,057 acres are in farms, 10,615,644 acres of which, or 40.2 per cent, are improved land. There were then 224,691 farms in the state. The total value of the farm property was $228,374,637. The total value of the farm products was $104,304,476. The values of the leading products were: Domestic animals, $33,499,683; dairy products, $5,954,575; cereals, $20,481,157; cotton, $48,981,532.

The land grant college of Georgia is a part of the University of Georgia at Athens, and is known as the Georgia State College of Agriculture and Mechanic Arts. The federal Experiment Station is a department of this college, but is located at Experiment, near Griffin. There are no sub-stations. The State Department of Agriculture, whose head is the State Commissioner of Agriculture, an elective officer, has its headquarters at the capitol in Atlanta.

This Department has charge of the inspection and analysis of commercial fertilizers and oils, and polices and regulates both industries. The State Board of Entomology, composed of three ex-officio members—the Commissioner of Agriculture and the Presidents of the State Agricultural and the State Horticultural Societies,—also has its headquarters at the capitol, and appoints a State Entomologist and assistants, who are charged with the inspection and police work in connection with the control of plant pests and maladies and with the supervision and inspection of nurseries. The University of Georgia has control of farmers' institute work, under the general supervision of the president of the State College. The State Agricultural Society, a corporate body, holds an annual fair, usually at Macon. The other more important agricultural societies are: The Georgia State Horticultural Society, The Georgia Fruit-Growers' Association, The Georgia Dairy and Live-stock Association and the Georgia Audubon Society.

FLORIDA. (By *C. M. Conner.*) Agriculture as it is understood in the North exists only in its infancy in Florida. The farming is various, as the state contains the only really tropical area in the United States, and many special crops are grown throughout most of the peninsula. Cotton-planting is confined to the northern or continental part. In the older

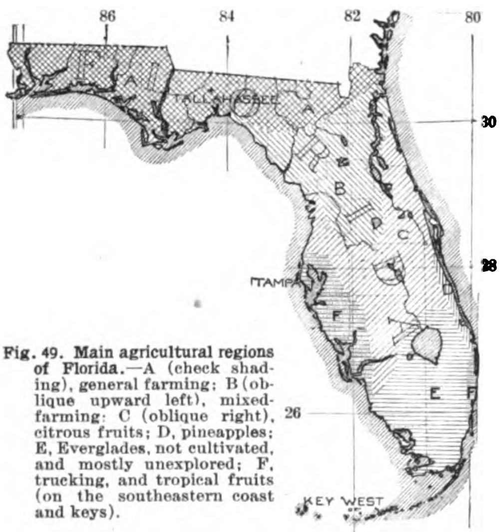


Fig. 49. Main agricultural regions of Florida.—A (check shading), general farming; B (oblique upward left), mixed-farming; C (oblique right), citrous fruits; D, pineapples; E, Everglades, not cultivated, and mostly unexplored; F, trucking, and tropical fruits (on the southeastern coast and keys).

sections of the state, on the red hills, we find the same type of farming as is found in Georgia and other cotton-growing sections, but in the central and southern parts the farms are small and confined to growing small quantities of sugar-cane, sweet-potatoes, corn and other general farm crops. Some truck is grown for the northern market, but this is confined mostly to the richer moist lands. The extensive range has furnished pasture for large numbers of cattle, but this is becoming more and more restricted each year. Some live-stock farms have been started during the last few years and are meeting with success.

The soils of the state are rather deficient in fertility, and require considerable commercial fertilizer to produce profitable crops. Most of the soils are sandy. There is a strip of red clay in the western part, but over the main body of the state there is sand, with more or less organic matter mixed with it. The whole state is rather low, the most of it being within fifty feet of the sea-level. Artesian water can be found in most sections, and is frequently used for irrigating.

The arable soils of Florida may be divided into two classes: hammock, and high pine land. The hammocks are higher sections of land covered with oak, hickory and other deciduous trees. They are irregular in size and have no definite location in the state. They may be found from one end of the state to the other, and vary in size from a few acres to many thousand. The hammock soils are richer and stronger—due to the great quantity of leaves and twigs falling from the deciduous trees and enriching the land. The leaves from the pine trees do not seem to add much to the fertility of the soil.

The arable pine lands are usually light and have no clay near the surface. Should there be clay near the surface, it causes the soil to be wet; this class of land is known as flat-woods pine land, and is usually regarded as unfit for cultivation.

The rainfall is not very evenly distributed, the greater part of the rain falling in June, July and August. No protracted droughts occur, however.

Transportation is confined mostly to the railroads. Rivers and lakes furnish transportation for short distances. The high rates constitutes one of the greatest drawbacks to the development of the country.

The total land area of Florida is 34,713,600 acres. Of this, according to the Twelfth Census Report (1900), 4,363,891 acres are in farms, 1,511,653 acres of which, or 34.6 per cent, are improved land. There were then 40,814 farms in the state. The total value of the farm property was $53,929,064. The total value of the farm products was $18,309,104. The value of the leading products were: Domestic animals, $10,687,632; cotton, $2,894,930; cereals, $2,906,332; vegetables, $3,040,358.

The University of the State of Florida, located at Lake City, receives the benefits of the land grant act. The federal Experiment Station is also located at Lake City, and is under the same Board of Control. The Commissioner of Agriculture and Immigration has his headquarters at Tallahassee, and is elected by the people. This office has charge of the fertilizer and feed inspection work. The state has no permanent state fair, but has local fairs at Tampa, Miami, DeFuniak Springs and Jacksonville. The leading agricultural societies are the State Horticultural Society, State Agricultural Society, State Live-Stock Association, State Poultry Association.

Eastern Tropical Florida. (By *John Gifford.*) The country referred to in this sketch includes that part of Florida between the Everglades and the Gulf stream and the islands, keys or cays, which extend from the neighborhood of Miami southwestward to Key West. This territory lies south of the twenty-sixth parallel, and, although difficult to estimate accurately in area, is probably larger than the state of Connecticut.

The vegetation corresponds to that of the Bahamas and western Cuba, and comprises many truly tropical species.

The main agricultural industries are the raising of winter vegetables, citrous fruits, mainly pomelo and lime, pineapples, and other tropical fruits, such as mangoes, avocados, guavas, sapodillas, sugar-apples. Other fruits in great variety are produced in small quantities for local consumption, such as papaws, surinam cherries, roselle, carissa.

Fig. 50. An island in the Everglades at high water.

The vegetable-growing is mainly confined to the glade land. Enormous quantities of tomatoes, eggplants, peppers and other vegetables are produced for shipment north and west in mid-winter. Fruits and vegetables of this region are exceptionally firm and fine-flavored. Crops on the glade are liable to suffer in heavy rains; in fact, most of this glade land is covered at times with water.

The second type of land is the pine land, mostly covered with *Pinus Elliottii.* It is similar to the provision land or pine-barren land of the Bahamas. It is a limestone ridge between the Everglades and the seashore. Although there are sandy swales and considerable sand mixed with the rock, its main fault is a scarcity of workable soil in proportion to the area. In places there are almost bare rocky reefs. Dynamite is extensively used in making tree holes and breaking the hard surface rock. This rocky soil is difficult to cultivate. It is seldom that plows or harrows can be used. In places this limestone has disintegrated into a yellowish and reddish marl. Land with loose, porous rock and plenty of reddish marl or yellow soil close to the surface is excellent for the pomelo. On both the pine and glade land large quantities of commercial fertilizer are used.

The third type of land is hammock. It is covered and enriched by a dense growth of tropical hard woods. It may be found here and there on the mainland, and covers the keys. It is naturally fertile. On this land pineapples and limes are extensively produced. Also, such fruits as sapodillas, dwarf bananas and sugar-apples thrive. On the hammock land the rank growth of tropical weeds is troublesome.

The climate is practically free from frost, the water-table is near the surface, and irrigation, although helpful, is not necessary.

Domestic animals do not thrive in this region, except poultry, although velvet beans, cowpeas and other legumes, chufas, kafir corn, cassava and other food materials grow well. Compared with the North or Cuba, the pasturage is poor, and flies and other insect pests are at times troublesome.

The chief advantages of the region are, first, its unsurpassed climate in winter, and second, its important geographical location. The keys are unique in that they are of coral formation and capable of producing the same fruits and vegetables that are produced elsewhere on coral islands in the tropics, in addition to what the sea yields in the way of wrecks, sponges and fishes. This region has been hampered by a lack of competition in transportation. The Florida East Coast Railroad has had the development of the region under its control, and, although much more might have been accomplished had it acted on a more liberal basis, nevertheless without it the region would still be, no doubt, unsettled and practically unexplored. This railroad is being extended across the keys to Key West, a gigantic engineering project. The channel from Miami to the sea is almost completed, so that both rail and water transit will soon be available to the whole region. Lines run direct from Miami to Cuba and Nassau, and Key West is a great entrepot.

The population consists of a large proportion of northern people, of "crackers" from up the state, and of "conchs" from the Bahamas, with a fair

Fig. 51. Hard pine lands bordering the Everglades. Southern Florida. (*Pinus Elliottii.*)

sprinkling of people from all parts of the world. The workmen are mainly Bahama negroes. Being accustomed to planting with a crowbar and weeding with a machete in their native land, they are good workmen, especially on the keys.

The keys, although highly productive, suffer in consequence of strong ocean winds, lack of fresh water from wells, and mosquitoes during the summer while lime and pineapple pickings are in progress.

The line of future development would seem to be in reclaiming flooded lands for vegetables and perhaps sugar-cane; the utilization of that part of the pine lands best suited to the pomelo, and a more careful cultivation of limes, pineapples and other choice tropical fruits on the keys. The northern taste must develop, also, to provide a market. No doubt the sisal and other fiber plants may be successfully grown on the rockiest land. In time, Red Ceylon and Peen-to peaches, choice grapes, vanilla, coffee, ceriman, kumquats, loquats, Surinam cherries, carissa and other choice tropical fruits and vegetables may be profitably grown in small quantities. Among the native trees there are many of value, such as mahogany, mastic and coccoloba.

Fig. 52. Drilling hole for tree planting in soft rock on the coast of southeastern Florida.

Both Miami and Key West are rapidly becoming great tourist as well as industrial centers, so that there is an ever-increasing local demand. A large quantity of fruit is now being used by canning and jelly factories.

Much of this territory is virgin and new, in fact, unexplored. It is awaiting people with capital and enterprise. The tide of immigration to the South is moving swifter every season. It is impossible to predict the future of such a vast territory, with such peculiar and unique conditions. In no place known to me do plants respond so quickly to touches of attention, or fail so quickly if neglected.

6. GULF-COAST COTTON STATES

ALABAMA. (By *J. F. Duggar.*) Agriculture is the leading industry of Alabama. Cotton is the chief product and the only sale crop on the majority of farms. Cotton and corn are produced in every county, as are also the usual vegetables and fruits of a temperate climate.

The northeastern part of the state is rugged and very largely forest-covered. The mountain tops of this elevated region are flat and the sandy soil is easily worked, and is adapted to fruits, vegetables and cotton.

In the eastern part of Alabama is a triangular area consisting of hilly country, constituting the piedmont plateau, or foot-hills. The soils of this region are derived from crystalline rocks and consist chiefly of either non-calcareous red clay or clay loam soils, or gray, sandy soils, in both of which loose, flinty stones abound.

The Appalachian valley region is the name given to an area just northwest of the piedmont plateau. This region is adapted to cotton, corn, and all of the small grains.

In the northern part of Alabama is the Tennessee valley region, one of the best agricultural districts in the state. The soil is of limestone origin, and the topography is slightly rolling. This soil responds readily to commercial fertilizers. Here corn is grown as a sale crop, and wheat, barley and red clover thrive. Apples are adapted to this region, and near Huntsville the growing of nursery stock is an important business. Cotton is still the leading crop.

The Gulf plains in Alabama may be divided into the central prairie region and the areas lying respectively north and south of this region. To the north is an area of varied topography and soils, including gravelly hills, level areas of sandy loam and clay loam soil and rich bottom lands. Much of the land is still covered with forests.

The central prairie region is a gently rolling area in the central and western parts of Alabama. The soil is a stiff, waxy, calcareous clay, designated as Houston clay. It is either black, reddish or gray. Although stiff and rather poorly drained, this is distinctively the alfalfa soil of Alabama, and the area devoted to this crop is rapidly increasing. While cotton continues to be the leading crop, many are now turning their attention to the production of alfalfa and Johnson grass hay for sale and to the raising of live-stock. Commercial fertilizers are not in general use, but their use is increasing. Forests of oak, hickory and ash once covered this region, but now the area in forest is insignificant.

Fig. 53. Gulf states — Cabins on sugar plantation.

South of the central prairie region, most of the soils are sandy. The prevailing forest tree, the long leaf or southern pine (*Pinus palustris*), gives the name to the region. Lumbering and turpentining are important industries. Except near the coast,

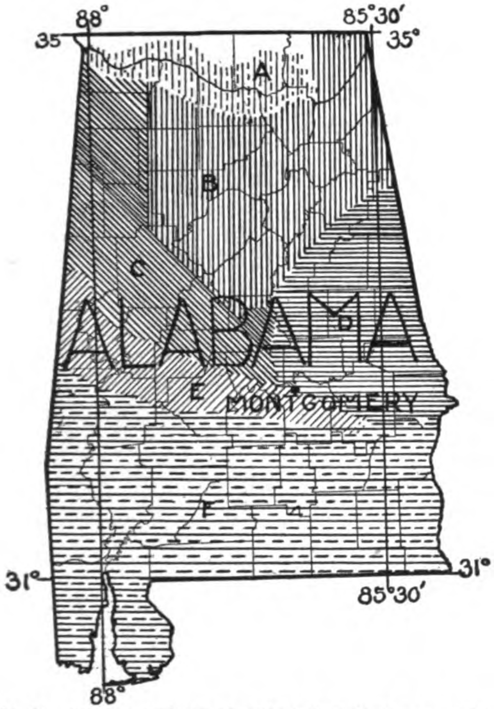


Fig. 54. Leading agricultural regions of Alabama.—A, cotton wheat, oats, corn, apples, cowpeas; B (mineral regions) fruit, vegetables, cotton; C, cotton, corn; D, cotton, oats, cowpeas, corn; E, alfalfa, cotton, corn, hay; F, cotton, sugar-cane, peaches, strawberries, vegetables, peanuts, cowpeas.

cotton is entensively grown, usually with the aid of commercial fertilizers. This is preëminently the fruit country of Alabama, and it is here that sugar-cane, sweet-potatoes and peanuts are most extensively grown. The rural population of the counties bordering on the Gulf coast are chiefly engaged in trucking and fruit-growing.

The total land area of Alabama is 32,985,600 acres. Of this, according to the Twelfth Census Report (1900), 20,685,427 acres are in farms, 8,654,991 acres of which, or 41.8 per cent, are improved land. There were then 223,220 farms in the state. The total value of the farm property was $179,399,882. The total value of the farm products was $91,387,409. The values of the leading products were: Domestic animals, $34,408,932; dairy products, $6,610,967; cotton, $42,069,677; cereals, $18,424,318.

The land grant college, formerly known as the Agricultural and Mechanical College, is now called the Alabama Polytechnic Institute. It is located at Auburn. It gives courses of instruction in agriculture and engineering subjects. The Agricultural Experiment Station is a department of it. The chemist of the Experiment Station is also state chemist and has charge of the chemical work of the state fertilizer control. There is a local experiment station at Uniontown, maintained by state funds, for the benefit of the central prairie region. There is an agricultural high school in each of the nine congressional districts. The teaching of agriculture is required in the public schools, except in towns having a population of 500 or more. There is a state Department of Agriculture and Industries, with headquarters at Montgomery. The Commissioner of Agriculture, who is located at Montgomery, is in charge of this Department. He conducts the administrative work of fertilizer inspection, coöperates with fair associations, holds farmers' institutes and advertises the resources of the state. Another series of farmers' institutes is conducted under the auspices of the Alabama Polytechnic Institute and Experiment Station. The fair at Birmingham has been assisted with state funds and the organization of a state fair is now in progress. The leading agricultural societies in the state are as follows: Alabama Division, Southern Cotton Association, Alabama Horticultural Society, Alabama Live-stock Association, Alabama Poultry and Pet Stock Association.

MISSISSIPPI. (By *W. L. Hutchinson.*) Mississippi borders on the Gulf of Mexico and has a fine, mild climate. The rainfall is abundant and well distributed, ranging between forty-five and sixty-five inches annually. The winters are not very cold nor the summers very hot.

The most of the state is from three hundred to five hundred feet above sea-level, some parts of it reaching eight hundred feet. The surface is rolling and sometimes hilly. The drainage and water-supply are good and there is also a valuable supply of underground water, there being thousands of artesian wells. The Yazoo-Mississippi Delta, between Vicksburg and Memphis, is nearly a level plain, the surface sloping just enough for natural drainage.

Fig. 55. Turpentine forest in the Gulf states.

The soils and climate are admirably adapted to the growing of a great variety of crops. Among field crops may be mentioned cotton, corn, wheat, oats, cowpeas, lespedeza, Bermuda grass, bur clover, melilotus, vetch, velvet beans, soy beans, sugar-cane, rice, sweet-potatoes and peanuts. Among garden and trucking crops may be mentioned tomatoes, strawberries, cabbage, beans, onions, potatoes, melons, cantaloupes and a great variety of kitchen-garden vegetables. Grapes do well, and also a number of orchard crops, such as peaches, plums, pecans, apples, figs and pears.

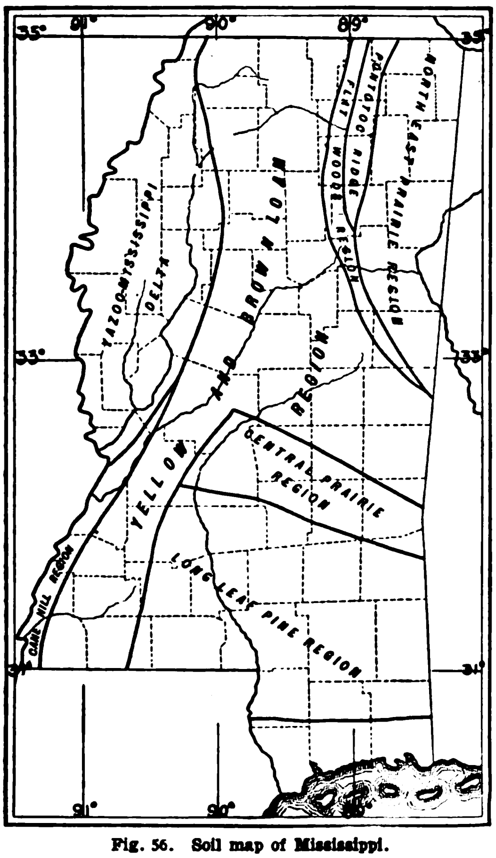


Fig. 56. Soil map of Mississippi.

Mississippi is one of the principal "cotton states." Cotton does well in all parts of the state except on the seacoast, the Delta being the best section. Other plants that are adapted to all parts of the state are corn, oats, sweet-potatoes, cow-peas, lespedeza, Bermuda grass, vetch, Johnson grass, melons, garden vegetables, strawberries, peaches, plums and grapes. Alfalfa does best in the northeastern prairie section and in the Delta. Sugar-cane does best on the sandy loam lands in the southern part. Carpet grass is an important pasture grass in the southern part.

Truck-gardening was first developed on the brown-loam soils along the Illinois Central railroad, but is now being extended to other lines of railways as well. It is well established at various points in the state, chiefly at Crystal Springs, Madison, Durant and Booneville. It is being started at many other places, such as Centerville, Magnolia, Water Valley, Laurel, Hattiesburg, Poplarville and McNeill. The best orchards are at Madison, Durant, Crystal Springs, Booneville, Meridian and Laurel.

Stock-raising is profitable when properly conducted, especially in the northeastern part of the state. Dairying can be practiced successfully in some parts with more ease and economy than in many more northerly sections of the Union.

Mississippi is preëminently a place for general agriculture, and those farmers who practice diversification are the most prosperous in the commonwealth. As far as natural conditions and advantages may determine the result, this state will always have a diversified agriculture; but two powerful influences will retard this diversification, one being the influence of capital and the other the disposition of a large part of the farming population not to succeed with anything but cotton.

The state has its full share of productive soils. In the Yazoo-Mississippi Delta are over four million acres in one solid body. Similar good soil is found in the broad valleys and creek and branch bottoms in other parts of the state. The northeastern prairie contains over three million acres of good soil in a body. The table-lands and rolling or hill lands, while not so productive as the bottoms and prairie, are often some of the most profitable farming areas, as they usually respond well to good treatment, commercial fertilizers and other manures.

The total land area of Mississippi is 29,657,600 acres. Of this, according to the Twelfth Census Report (1900), 18,240,736 acres are in farms, 7,594,428 acres of which, or 41.6 per cent, are improved land. There were then 220,803 farms in the state. The total value of the farm property was $204,221,027. The total value of the farm products was $102,492,283. The values of the leading products were: Domestic animals, $40,843,300; dairy products, $6,064,513; cereals, $19,317,968; cotton, $54,032,341.

The Agricultural and Mechanical College of Mississippi is located at Starkville. The federal Experiment Station is a department of it. There are three sub-stations, one at McNeill, one at Holly Springs and one at Stoneville. The professor of chemistry at the Agricultural and Mechanical College is ex-officio state chemist and has charge of the inspection of fertilizers on sale in the state. The college also has charge of the farmers' institute work. There is a State Cotton Association, a State Poultry Association and a State Cattle Association.

LOUISIANA. (By *W. R. Dodson.*) Louisiana presents three special types of agriculture,—the production of cane-sugar, rice and cotton. The production of truck crops and oranges may be added as of minor importance.

The production of cane is mainly limited to the alluvial lands south of the area of Baton Rouge and east of Lafayette. Excluding occasional rice fields and the extreme lower river and bayou coasts, sugar is almost the exclusive product of this territory. The rich alluvial land and comparative immunity from severe freezes limits the cane region to its present area.

In the vicinity of Shreveport and Alexandria, in the Red River bottoms, considerable attention is devoted to alfalfa, where the crops are harvested from four to six times each year.

Truck crops for shipment are mainly limited to the territory contiguous to the Illinois Central railroad from Ponchatoula to the state line, to the lower Mississippi and Bayou Lafourche, and the islands on the coast. Large quantities of strawberries, cabbage, radishes, beans and cucumbers are shipped to the early markets of the North. The sections more remote from transportation facilities produce potatoes, onions and cabbage. Oranges are grown only in the extreme southern part of the state, the largest number of producing trees being on the lower Mississippi. The northern and western parts of the state are developing the truck and fruit industries, mainly growing peaches, tomatoes, potatoes and melons.

From Lafayette to the western border of the state, in a belt varying from twenty to sixty miles in width, rice is the exclusive farm crop. The region devoted primarily to rice is especially suited for this crop, there being abundant fresh-water supply from bayous and artesian wells for irrigating the rice. The land is level, so that large fields can be secured with few levees. The soil is underlaid with a stiff clay that prevents loss of water from seepage into the lower strata. The soil becomes firm quickly after the irrigating water is withdrawn, enabling the use of most improved harvesting machinery.

In the remainder of the state, cotton production is maintained mainly as the money crop, from the fact of its adaptability to the labor conditions.

The profitable production of alfalfa is limited to the alluvial lands, the very stiff soil giving the best returns. Hill lands are not suited to the growth of the plant.

The production of Perique tobacco is limited almost entirely to St. James Parish, in the southern part of the state. Soil and climatic conditions produce a flavor that cannot be secured elsewhere.

The development in the future will be mainly along the lines already established, with an increased amount of attention to the production of live-stock. The great hindrances to the development of this industry have been the Texas fever and unreliable labor. It is now possible successfully to combat the Texas fever, and it seems to be a reasonable hope that the labor problem will be partially solved by securing the proper kind of immigration.

Fig. 57. Double negro cabin on the Mississippi delta.

The building of new railroads, the construction of drainage canals, and the extension of the levee system, is opening up much valuable land for farming purposes.

The total land area of Louisiana is 28,000,000 acres. Of this, according to the Twelfth Census Report (1900), 11,059,127 acres are in farms, 4,666,532 acres of which, or 42.2 per cent, are improved land. There were then 115,969 farms in the state. The total value of the farm property was $198,536,906. The total value of the farm products was $113,645,-495, in 1903. The leading products, according to a state report of 1903, were: Cotton and cotton seed, $48,057,038; sugar and molasses, $28,689,925; corn, $12,469,262; rice, $9,655,537.

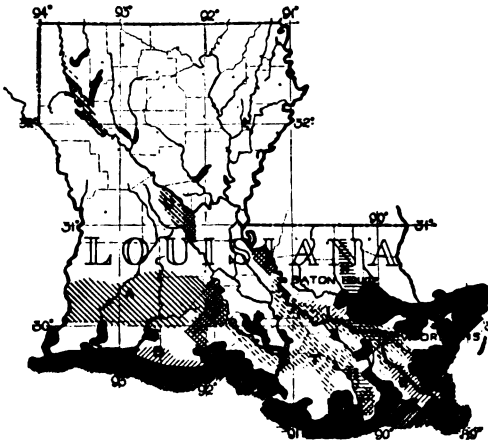


Fig. 58. Distribution of leading crops in Louisiana.—A, rice, almost exclusively; B, oranges and rice; H, truck-growing; I, rice of secondary importance; T, sugar-cane, almost exclusively; U, large fields of alfalfa; V, sugar-cane and cotton.

The Louisiana State University at Baton Rouge receives the benefits of the land grant act; the federal Experiment Stations are a part thereof. The Central Experiment Station is located at Baton Rouge. There is a well equipped sugar station at Audubon Park, New Orleans, and a station at Calhoun. There is a State Department of Agriculture, with headquarters at Baton Rouge, in charge of the Commissioner of Agriculture. This office is to be elective after 1908. This Department has charge of the inspection of fertilizers and feed stuffs, and has a supervisory relation to the experiment stations, and has supervision of the farmers' institute work. There is no state fair, but there is a movement on foot to establish one. The following are the leading agricultural and horticultural societies: The State Agricultural Society, the State Horticultural Society and the State Live-Stock Breeders' Association.

TEXAS. (By *E. J. Kyle.*) There are four principal types of agriculture in Texas,—general agriculture, or the growing of cotton and the cereals; fruit-growing; trucking; stock-raising.

General agriculture is confined principally to the eastern half of the state, reaching a little to the west in the northern part and not extending farther south than San Antonio. Cotton is fairly well distributed over this entire section, the greatest production being confined, however, to the black-land districts and the great Brazos and Colorado bottoms.

Corn-growing is confined principally to the same section. Wheat and oats are grown principally in the northern and northwestern sections, while rice-culture is conducted in the coast country, extending some twenty-five to fifty miles inland.

The fruit belt lies in the northeastern section.

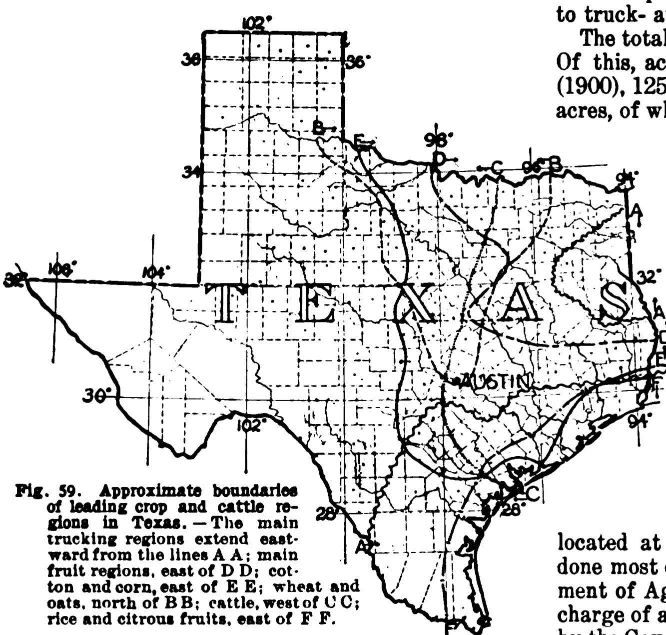


Fig. 59. Approximate boundaries of leading crop and cattle regions in Texas.—The main trucking regions extend eastward from the lines A A; main fruit regions, east of D D; cotton and corn, east of E E; wheat and oats, north of B B; cattle, west of C C; rice and citrous fruits, east of F F.

Extensive plantings of citrous fruits, especially the Satsuma orange, are now being made in the coast country.

Truck-farming is conducted in the extreme eastern section of the state, beginning with tomatoes in the northeast, cabbage, cauliflower and bunch vegetables in the coast country and ending with onions in the region south of San Antonio. This interest is now assuming vast proportions.

The great ranching or stock section begins in the northwestern and extends to the southeastern part of the state. Many hogs are now being grown in the northern and northeastern parts.

The rainfall varies from forty-five to fifty-five inches within a radius of 100 miles from Houston, to eight and ten inches in the southern and western half of the state, where crops are grown almost altogether under irrigation. In north Texas the temperature often falls below zero, while frost seldom occurs in the region south of San Antonio.

There are no real mountains in Texas, although there are some large hills in the central, northeastern and western sections. The altitude varies from a few feet along the coast country to 2,000 to 2,500 in the western part. Soil ranges from the stiff, black, waxy soil in the north, central and parts of the coast country, to a light, sandy soil which is found mainly along the coast in the south and nearly the whole of west Texas. In the northeastern section are the red and sandy loam soils.

The eastern part of the state has first-class railroad facilities, while Galveston is an extensive port from which most of the cotton and grain grown in the state are shipped. The state is so large and there is such diversity of climate and soil, that no one branch of agriculture is likely to develop much more rapidly or extensively than another, although it seems at present that more attention is being given to truck- and fruit-growing than to any other line.

The total land area of Texas is 167,865,600 acres. Of this, according to the Twelfth Census Report (1900), 125,807,017 acres are in farms, 19,576,076 acres, of which or 15.6 per cent, are improved land. There were then 352,190 farms in the state. The total value of the farm property was $962,476,273. The total value of the farm products was $239,-823,244. The values of the leading products were: Domestic animals, $236,227,93 4; dairy products, $15,510,978; cotton, $96,729,304; cereals, $47,132,566.

The Texas land grant college, together with the federal Experiment Station, is located at College Station. The state has two substations, one located at Beeville, founded in 1895, which devotes most of its time to vegetables, subtropical fruits and problems of irrigation. The other, located at Troupe, was founded in 1902, and has done most of its work with fruit. The State Department of Agriculture has headquarters at Austin, in charge of a Commissioner of Agriculture appointed by the Governor. The Commissioner is an ex-officio member of the Board of Directors of the College and also has control of the nursery inspection. The state fair is permanently located at Dallas. The Farmers' Congress is composed of the following organizations: State Horticultural Society, State Cotton Growers' Association, Texas Dairymen's Association, Texas Jersey Cattle Club, Texas Live-Stock Association, Southern Cotton Growers' Association, Texas State Floral Association, South Texas Truck and Fruit-Growers' Association, Southern Texas Truck Growers' Association, Texas Bee-Keepers' Association, Texas Poultry, Pigeon and Pet

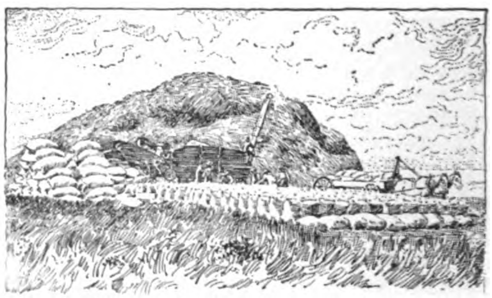


Fig. 60. Rice threshing.

Stock Association, Texas Nurserymen's Association, Women's Industrial Section, Red-Poll Cattle-Breeders' Association and Texas and Louisiana Rice-Growers' Section.

7. WESTERN COTTON STATES AND TERRITORIES

ARKANSAS. (By *R. W. Wade.*) There are two types of agriculture in Arkansas. To the first might be given the name of general farming, as it includes grain- and fruit-growing and stock-raising. The second type is more specialized, being almost exclusively the growing of cotton and corn. Alfalfa-growing in the northeast is possibly extensive enough to be classed as a third type.

The general farming and fruit area comprises the northwestern part of the state (see map), while cotton and corn culture occupy almost exclusively the south and east. Owing to the temperate climate of the northern part of the state, cereals and corn can be profitably grown, while the fruit-grower and truck-farmer find it a veritable garden. Because of the high altitude of the northwestern division, the season is rather too short for cotton-growing, and, owing to its hilly nature, a great deal of this section is best suited to grazing. There is an abundance of natural grass, and, as the winters are seldom severe, stock may be grazed nearly the entire year.

The rainfall is abundant over the whole of the state, and is well distributed to meet the needs of the agriculturist.

The southern and eastern parts of the state are lower than the northwestern division, and are made up of river valleys. The soil ranges from a dark sand, at Little Rock, to the black soil (buckshot) and yellow soils (gumbo) at the extreme south. All of these soils are very productive, and it is owing to their almost inexhaustible fertility that cotton and corn still remain the staple crops of this region.

Although the state has good transportation facilities by water, the railway system is not complete enough, as yet, to furnish the farmer easily accessible markets for his produce. Owing to the lack of railways and the high transportation rates, the fruit-growers of the northwest are unable to realize such profits as the favoring climate and the fertile soil warrant.

The northwest, as it gets better transportation facilities, will develop into one of the finest fruit districts in the world; and the southern and eastern division, when guarded from the Mississippi by levees, and thoroughly drained, will still produce cotton, corn and alfalfa as the staple crops; more and better stock will be kept, and Arkansas will sell more produce at less expense to soil fertility.

The total land area of Arkansas is 33,948,800 acres. Of this, according to the Twelfth Census Report (1900), 16,636,719 acres are in farms, 6,953,735 acres of which, or 41.8 per cent, are improved land. There were then 178,694 farms in the state The total value of the farm property was $181,416,001. The total value of the farm products was $79,649,490. The values of the leading products were: Domestic animals, $35,739,425; dairy products, $6,912,459; cotton, $28,053,813; cereals, $20,233,270.

The University of Arkansas, at Fayetteville, is the recipient of the land grant funds. The federal Experiment Station is a department of it. There are three sub-stations,— one at Danville, one at Ferguson, and the third not yet definitely located; also a rice farm at Lonoke. There is a State Department of Agriculture, with headquarters at Little Rock, in charge of the Commissioner of Agriculture, who supervises the agricultural interests of the state. The state fair is located at Rogers, and is a private and local organization. The state entomologist, who is on the station staff, has charge of nursery inspection, while the veterinarian of the Experiment Station staff has charge of live-stock inspection for contagious diseases. There is a State Horticultural Society and a Live-Stock Association. Many counties have fruit-growers' associations for mutual benefit in marketing and shipping fruit. Poultry breeders have also organized clubs. The farmers have formed a protective association for mutual benefit in selling farm products.

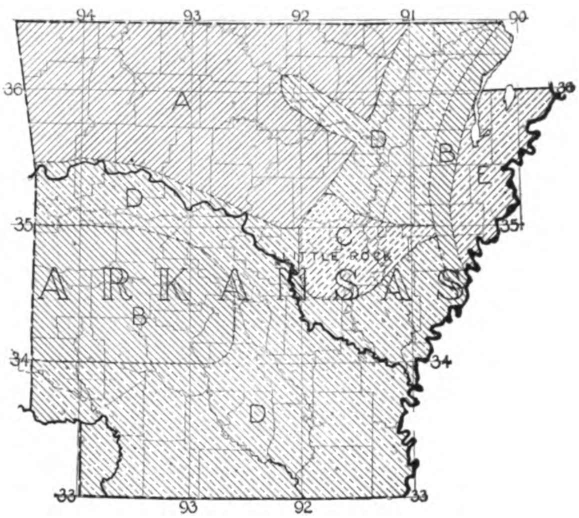


Fig. 61. Main agricultural regions in Arkansas.—A, fruit and general farming; B, fruit; C, rice; D, cotton and corn; E, alfalfa. Much of the state is in forest.

INDIAN TERRITORY. (By *J. Fields.*) Agriculture in Indian Territory is in an undeveloped stage, the business up to the present time having been for the most part conducted by tenant farmers who have leased from the Indian owners. These conditions are changing rapidly. In the southern half of the territory, corn and cotton are the chief products. In the northern part, cotton is replaced by wheat. The rainfall averages nearly forty inches, and with the long growing season, crops in great variety are grown successfully.

Oklahoma and Indian Territories logically belong together. The character of the agriculture within the area is modified by the gradually decreasing rainfall from the east to the west. The eastern parts more nearly correspond to the farming regions of the Middle West, while the western part of the area is deficient in rainfall, and special knowledge of proper methods is required for successful farming there. [The "statehood bill," for the admitting of these territories as one state, is pending as these pages are being read.]

The total land area of Indian Territory is 19,-

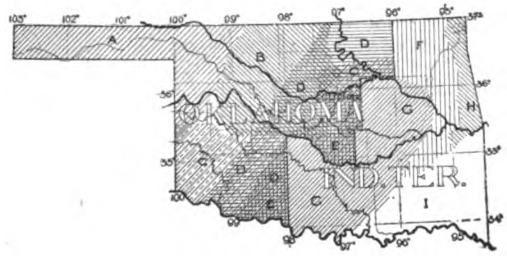


Fig. 62. The agricultural regions of Indian Territory and Oklahoma.—A, grazing and drought-resisting crops; B, wheat; C, cotton; D, corn; E, fruit; F, wheat, corn, hay and some fruit, cotton and wheat in south; G, corn, wheat, alfalfa, (possibly fruit later); H, fruit, general farming; I, undeveloped, coal-mining, mountainous.

840,000 acres. Of this, according to the Twelfth Census Report (1900), 7,269,081 acres are in farms, 3,062,193 acres of which, or 42.1 per cent, are improved land. There were then 45,505 farms in the territory. The total value of the farm property was $92,181,615. The total value of the farm products was $27,672,002. The values of the leading products were: Domestic animals, $40,824,886; dairy products, $1,504,747; cotton, $5,407,052; cereals, $9,017,568.

OKLAHOMA. (By *J. Fields.*) Midway between the North and the South, and on the border line between deficient and ample rainfall, developed in a short period of time by farmers from every state in the Union, the agriculture of Oklahoma covers an unusually wide range of types. Originally consisting entirely of the pasturing of range cattle, this industry is now practically pushed out, still lingering only in Woodward and Beaver counties, in the northwestern part of the territory.

Corn, wheat and cotton, a most unusual combination, constitute the chief crops grown for market. In general, wheat is most largely grown in the north-central part, corn in the eastern half, and cotton in the southern half, but cotton is grown in every county except two, and wheat and corn in every county.

In the same way, commercial orcharding and gardening are largely confined to the eastern third, but nearly every farm has its home orchard and garden. Kafir corn is an important substitute for corn in the western half and has made profitable crops possible on lands unsuited to corn.

Rainfall and temperature determine the principal crops. From an annual average of forty inches along the eastern border, the precipitation decreases gradually to about twenty inches along the northwestern border, and to less than that amount in western Beaver county. A fortunate distribution of the rainfall makes it possible to grow better crops than the above figures would indicate. On the average, two-thirds of the precipitation occurs during the months from April to September, the time from October to March being comparatively dry. Cotton-growing is being carried farther north, but it is not a safe crop in the northern half of the territory.

The cattle industry is hampered by quarantine restrictions against cattle from Texas fever districts, and more attention is being given to hog-raising and the production of good horses and mules. A marked development of dairying is apparent. Forage crops, including alfalfa, are easily produced. An increased acreage is being sodded to Bermuda grass for permanent pasture. Locally manufactured feeds, such as bran and cottonseed meal, are available, and markets for the output of creameries are convenient.

Oklahoma will always represent the widest diversification of crops, and it is doubtful whether any state can produce such a great variety of crops on a profitable basis. This makes for certainty of returns each year and minimizes the effect of even an entire failure of any one crop.

The total land area of Oklahoma is 24,851,200 acres. Of this, according to the Twelfth Census Report (1900), 15,719,258 acres are in farms, 5,511,994 acres of which, or 35.1 per cent, are improved land. There were then 62,495 farms in the territory. The total value of the farm property was $185,343,818. The total value of the farm products was $45,447,744. The values of the leading products were: Domestic animals, $53,921,827; hay

Fig. 63. The round-up and branding in the Oklahoma country.

and forage, $2,883,682; dairy products, $2,481,-673; cereals, $19,093,722.

The Agricultural and Mechanical College at Stillwater is the agricultural college of Oklahoma, but it receives no revenue from the act of 1862. The federal Experiment Station is a department of it. The Board of Agriculture, composed of the Governor and six members elected by delegates from chartered county farmers' institutes, is charged with the enforcement of the nursery, fertilizer, and feeding-stuffs inspection laws. The Secretary of the Board, in coöperation with the Experiment Station, superintends the work of farmers' institutes. The leading agricultural societies are as follows: Horticultural Society, Cattlemen's Association, Improved Stock-Breeder's Association, Shorthorn-Breeders' Association, Corn-Breeders' and Growers' Association and Dairymen's Association. There are several poultry societies, but no territorial poultry association. Neither is there a territorial fair association, though many local fairs are held each year.

8. CORN-BELT STATES

OHIO. (By *C. E. Thorne.*) Ohio possesses a soil and climate admirably adapted to the growth of maize, oats and winter wheat; from its earliest occupancy by the white man the production of these cereals has been the leading agricultural industry of the state.

All kinds of fruits and plants that will endure freezing temperature find here a congenial home, especially along the lake shore and on the hills in the southern part of the state.

Pasture grasses flourish almost everywhere, and the keeping of live-stock has always been a prominent feature of the agriculture of the state, although this industry has not kept pace with grain production since the exploitation of the free ranges of the West.

Throughout the state a more or less systematic rotation of maize, oats, wheat, clover and timothy is practiced, the oats crop being frequently omitted in the southern counties. In the hilly counties the crop yields are invariably lower than on the more level land. These counties are naturally adapted to orcharding and the pasturage of sheep, industries which have been more prominent in the past than at present, but which it is believed will be revived in the future. In the northwestern quarter of the state is a great area of black soil, once semi-swamp, now reclaimed by drainage, an area which is leading the state in the production of maize. The northeastern counties, with large areas of cold, clay soil, have been celebrated for dairy products, while the southwestern counties, through which flow the two Miamis, with their fertile valleys and scarcely less fertile uplands between, have been the richest region of the state in natural advantages, and are likely to prosper again when a better method of soil management shall have restored the fertility that has been wasted because of its very abundance.

Topographically the state is a great flat plain, lying at an average altitude of about one thousand feet above the sea, rising to fifteen hundred feet in a few isolated hills and dropping to six hundred or seven hundred feet along the lake shore and in the narrow valleys of the Ohio and its tributaries.

The Ohio river, forming the southern and southeastern boundary of the state for several hundred miles, and Lake Erie, constituting the larger part of the northern boundary, furnish natural highways which contributed much to the early prosperity of the state. Lying, as it does, in the pathway between the East and the West, it has become netted with some nine thousand miles of railway, and several large cities and many smaller ones have grown up within its borders or within easy reach, thus giving an urban population of several millions within a night's ride of the center of the state. This means that the agriculture of the state will more and more drift into the production of perishable commodities which command relatively high

Fig. 64. General distribution of Ohio agriculture.— Hill counties, orcharding, sheep-pasturing; Miami valley, richest section of the state; dairy counties, dairying; grain and hay in other sections.

prices, and into the fattening of animals grown on cheaper lands.

The total land area of Ohio is 26,086,400 acres. Of this, according to the Twelfth Census Report (1900), 24,501,985 acres are in farms, 19,244,472 acres of which, or 78.5 per cent, are improved land. There were then 276,719 farms in the state. The total value of the farm property was $1,198,-923,946. The total value of the farm products was $257,065,826. The values of the leading products were: Domestic animals, $120,466,134; hay and forage, $29,047,532; dairy products, $25,383,-627; cereals, $91,748,320.

The Ohio State University, located at Columbus, is the land grant institution of the state. Within it is organized a College of Agriculture and Domestic Science. The Ohio Agricultural Experiment Station was organized independently of the University in 1882, and is the beneficiary of the national experiment station law. It is at Wooster. It has three sub-stations, or test farms, located in Cuyahoga, Montgomery and Meigs counties. The Ohio State Board of Agriculture, an elective body, performs the functions of a state department of agriculture. This Board, or its secretary, is charged with the inspectional and police work of the state as it affects agriculture, with the management of the state fair, which is permanently located at Columbus, and with the control of farmers' institutes. The leading agricultural associations are the Ohio State Horticultural Society, the Ohio Merino Sheep-Breeders' Association, the Ohio Wool-Growers' and Sheep-Breeders' Association, the Improved Delaine Merino Sheep-Breeders' Association, the Ohio Shorthorn-Breeders' Association, the Ohio Horse-Breeders' Association, the Ohio Plant-Breeders' Association, the Ohio Dairymen's Association, the Association of Fair Presidents and Secretaries, the Ohio Agricultural Student Union and the Ohio State Forestry Society.

INDIANA. (By *A. T. Wiancko.*) With the exception of a few counties in the northeastern corner, and a narrow strip near Lake Michigan, the state of Indiana slopes gently in a southwesterly direction, draining into the Ohio river at the southwestern corner at an elevation of 370 feet above sea-level. The highest elevation, 1,140 feet, is in Randolph county, about half-way up the east side of the state. The northeastern part of Indiana is rolling and contains numerous small lakes. The soil here is mostly a clay loam, with some level, dark, loamy areas and numerous small mucky depressions. There are considerable areas of sandy, and of flat and marshy land in the northwestern part of the state. Much of this section is still too wet for general cultivation, but drainage operations are proceeding rapidly. Twenty-five to one hundred miles south from Chicago there are large areas of muck soil.

The Wabash valley is generally of a loamy nature and well suited to all branches of agriculture. The middle part of the state to the east and south of the Wabash valley is generally rolling, with a rich loamy soil, inclining to be clayey along the eastern side. The southern part of the state, with the exception of the Wabash valley on the west and the White river valley extending southwest from Indianapolis, is hilly, especially the three southern tiers of counties, and the soil is almost all clayey and often lacking in fertility. The prairie regions of the state are practically confined to the northwestern corner.

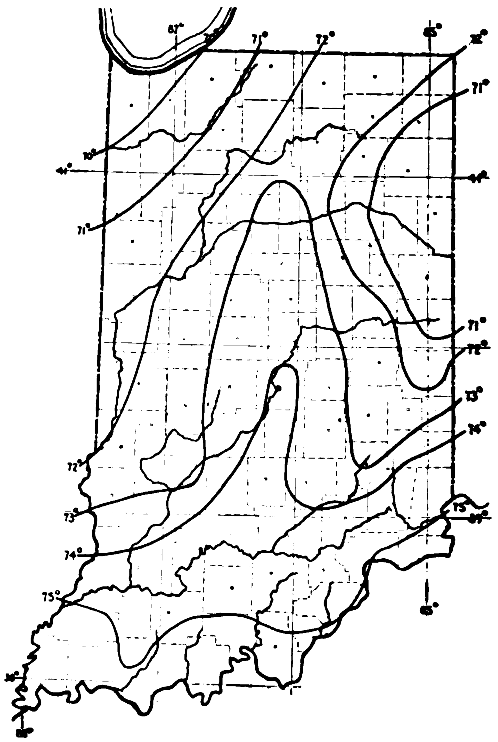


Fig. 65. Map of Indiana, showing isotherms. — The state is very homogeneous in agricultural **possibilities, having few** very well-marked special agricultural **areas (excepting the** muck-lands in the northwest).

The climate of Indiana is favorable to general agriculture. The mean annual temperature is about fifty-two degrees Fahrenheit, and for the growing months is about seventy degrees. The mean annual rainfall is about thirty-nine inches, and is well distributed throughout the year. Periods of extended drought are rare. As a whole, the state is well watered.

Corn is the principal crop everywhere, the central and western sections being foremost and producing the finest corn in the world. Winter wheat is also universally grown, except in the prairie region of the northwest, the southern counties leading. The value of the wheat crop amounts to about $20,000,-000 annually. Oats are also largely grown, especially in the north-central and northwestern regions. Barley and rye are very little grown. Clover is an important crop all over the state, both for hay and for seed. Timothy is also largely grown and well distributed, and orchard-grass is an important crop in the southeast. Alfalfa is being introduced successfully in many sections and promises to be an important crop. The potato crop is relatively unimportant, though the natural conditions are generally favorable. The total annual value of horticultural products amounts to about $12,000,000. About one-third of this is fruits, produced in southern and central Indiana. The third important onion-producing center of the United States is in northern Indiana. Peppermint and celery are also largely produced in the north. In the southwest, large quantities of melons are grown. Indiana is in many ways well suited to horticultural production, and fruit-growing, especially apples, and vegetable-growing have bright futures.

The live-stock interests of Indiana are large, hogs and cattle leading. Hogs yield about one-half the annual income from this source. The natural conditions for dairying are excellent, but the business is crowded out by corn and hogs.

The market facilities are good. The state has a regular network of railways and electric-car lines leading to important centers of consumption, of which Chicago, Indianapolis, Louisville and Cincinnati are the chief. Along the Ohio river, water-transportation facilities take care of a large amount of produce.

While corn production promises to remain the principal branch of Indiana agriculture for some time to come, the most promising fields for development are in the lines of live-stock, dairying and horticulture.

The total land area of Indiana is 22,982,400 acres. Of this, according to the Twelfth Census Report (1900), 21,619,623 acres are in farms, 16,680,358 acres of which, or 77.2 per cent, are improved land. There were then 221,897 farms in the state. The total value of the farm property was $978,616,471. The total value of the farm products was $203,000,-000. The approximate annual values of the leading products were: Field crops, including hay and grain, $130,000,000; domestic animals, $45,000,000; dairy products, $16,000,000; horticultural products, including vegetables, $12,000,000.

The land grant institution of Indiana bears the name of Purdue University and is located at Lafayette. In connection with this is the federal Agricultural Experiment Station. There is a State Board of Agriculture, with headquarters at Indianapolis. This body receives some support from the state. The state fair is located permanently at Indianapolis and is managed by the state board of Agriculture. There is an extensive system of farmers' institutes, under the supervision of the Purdue University School of Agriculture. The leading agricultural societies in the state are as follows: Indiana Horticultural Society, Indiana Corn-Growers' Association, Indiana Live-stock Breeders' Association, consisting of a federation of various animal breeders' societies, Indiana State Dairymen's Association and Indiana Potato-Growers' Association.

ILLINOIS. (By *J. G. Mosier.*) Illinois is primarily an agricultural state. Almost all types of agriculture are practiced to a greater or less extent throughout the state. Illinois led the states in total agricultural wealth at the last census.

The demand for milk in the cities of Chicago and St. Louis has caused dairying to develop around those places as centers. It is of secondary importance over a much larger area. Facility for quick transportation is an essential factor in the development of this business. Stock-raising and feeding, while generally practiced, are best developed in the west-central and northern parts, where large numbers of hogs and cattle are fattened every year.

Fruit-growing on a commercial scale is especially well developed in an area extending from the southeast-central to the southwest-southern part, the northern part of this region being the center of the fruit-growing area of the state. These fruits comprise apples, pears, plums and strawberries. Well-adapted soil, coupled with good transportation facilities, determine the distribution of fruit-growing. Apples are extensively grown in an area stretching to the mouth of the Illinois river north into the deep loess-covered area to the latitude of Keokuk. Truck-growing is conducted in small areas near centers of consumption, as around Chicago and St. Louis,

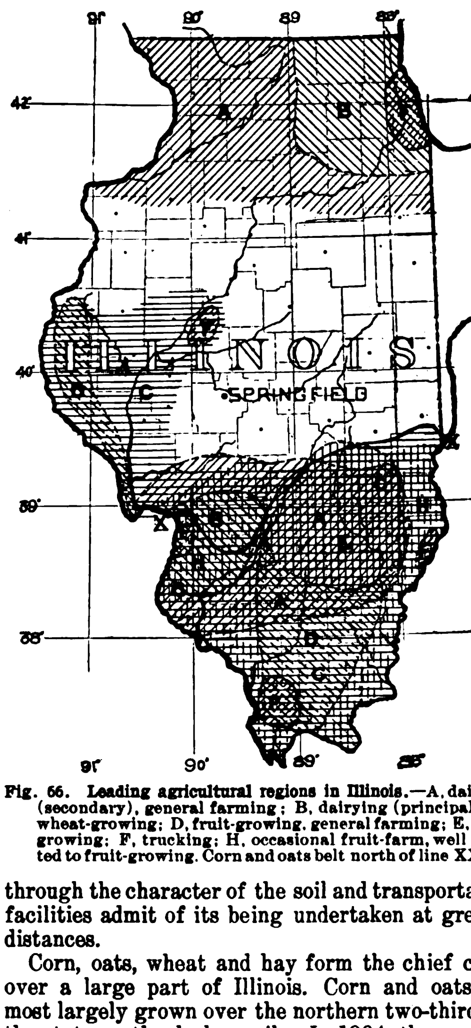


Fig. 66. Leading agricultural regions in Illinois.—A, dairying (secondary), general farming; B, dairying (principal); C, wheat-growing; D, fruit-growing, general farming; E, fruit-growing; F, trucking; H, occasional fruit-farm, well adapted to fruit-growing. Corn and oats belt north of line XX.

through the character of the soil and transportation facilities admit of its being undertaken at greater distances.

Corn, oats, wheat and hay form the chief crops over a large part of Illinois. Corn and oats are most largely grown over the northern two-thirds of the state on the darker soils. In 1904, the acreage of these two crops constituted at least one-third of the entire area of the state, and their value was $142,688,833. Wheat is grown rather extensively in the general farming of the southern third and in the southwestern part of the central division. Winter wheat only is grown, and the crop is very well adapted to both the soil and the climate. Hay is grown throughout the entire state, but much more extensively in some parts than in others. The underdrained swamps of the northern part produce large amounts.

The state lies almost entirely within the area of glacial drift, and, as a consequence, the soils have been formed to a large extent by transported material. The glacial topography gives rise to rolling prairies. The larger part of the northern two-thirds of the state is prairie, formed by the glacial drift, and the soil is a dark brown silt loam, very fertile and well adapted to growing corn, oats and grass. Timber usually occupies small areas along streams, and here the soil is usually a gray silt loam, better adapted to grass and wheat, although corn and oats produce fairly well on it. The soil of the southern third is a gray silt loam well adapted to growing fruits, especially apples, wheat, grass and cowpeas. Alluvial land is found along the many streams, giving a soil of the highest productive capacity.

Illinois possesses a climate well suited to the requirements of a great agricultural commonwealth. The rainfall is well distributed throughout the state, the average annual fall being 37.39 inches. The average annual temperature of the state is 52.3 degrees Fahrenheit, varying from 48.9 degrees in the northern district to 55.9 degrees in the southern. The length of time between killing frosts in spring and fall, 155 days in the northern part and 195 days in the southern, gives a season sufficiently long for maturing the crops.

The total land area of Illinois is 35,840,000 acres. Of this, according to the Twelfth Census Report (1900), 32,794,728 acres are in farms, 27,699,219 acres of which, or 84.5 per cent, are improved land. There were then 264,151 farms in the state. The total value of the farm property was $2,004,316,897. The total value of the farm products was $345,649,611. The values of the leading products were: Domestic animals, $186,856,020; dairy products, $29,638,619; hay and forage, $25,568,619; cereals, $164,784,437.

The land grant institution is the University of Illinois, at Urbana, at which place is the College of Agriculture and also the Agricultural Experiment Station, founded in 1888. There are no regular substations, but experiment fields are located in different parts of the state and are leased long enough to demonstrate the problems being investigated in that particular locality. There is a State Board of Agriculture, with headquarters at Springfield, consisting of a president, vice-president at large, secretary-treasurer, and a vice-president from each congressional district. It has charge of the crop reports and agricultural statistics of the state. The state fair is located permanently at Springfield and is in charge of the State Board of Agriculture. The Illinois Farmers' Institute governing body consists of twenty-five men, one from each congressional district. The leading agricultural organizations are as follows: State Dairymen's Association, Live-stock Breeders' Association, which includes the following branches: Illinois Horse-Breeders' Association, Illinois Swine-Breeders' Association, Illinois Cattle-Breeders' Association, Illinois Sheep-Breeders' Association and Illinois Cattle-Feeders' Association; Illinois Horticultural Society, the Northern Central and Southern Horticultural Associations, Illinois State Poultry Association, Illinois State Grange and Illinois Live-stock Commission.

IOWA. (By *Charles F. Curtiss.*) The state of Iowa is in about the center of what is termed the great Mississippi valley, lying between the Missouri and the Mississippi rivers and between 39½ degrees and 43½ degrees latitude north. Its surface and soil are very uniform and well suited to agricultural purposes. About ninety-seven per cent of the entire area of the table is considered tillable land, or might be made tillable by drainage. The soils, of the state come under four classes: Geest, or decomposed local rock; alluvium, or stream-made soils; loess, or wind-made soils; till, or soils of glacial origin. The state is generously supplied with small streams that are tributary to the Mississippi and Missouri rivers. The surface of the land is generally undulating, though some sections are nearly level. Adjacent to nearly all the larger streams is a strip of level alluvial soil, while in the southern, eastern and central parts of the state these streams are generally supplied with a small timber belt, though the natural timber of the state is rapidly disappearing. These bottom-lands are sometimes submerged, but as a rule they average as well in productiveness as other types of soil.

The natural and economical conditions surrounding the state are all such as to favor considerable diversity in its agriculture. The state is abundantly supplied with railroads. Its proximity to good markets and the richness and resources of its soils have developed diversified farming in all sections of the state. In the last census it ranked second to Illinois in total agricultural wealth. It is preëminently devoted to grain-raising, stock-feeding and dairying. Among the grains, corn ranks as the leading crop. When the soils began to show signs of depletion, dairying and stock-feeding were undertaken to maintain the fertility of the land. Dairying originated in the northeastern part of the state, but it has since extended to all sections, so there is no longer a dairying region of Iowa. The same is largely true of other phases of agriculture, though perhaps the central and western sections are more largely devoted to stock-feeding than other parts of the state. The live-stock interests have always been prominent, and no other state feeds so large a proportion of the grain products which it raises. Probably for this reason, and because of the large area devoted to grazing and stock-raising, the state has not yet reached the commercial fertilizer stage. Scarcely any commercial fertilizers have thus far found a market in Iowa, and it is believed that as long as intelligent methods of agriculture are followed no necessity for them will arise. There are indications that the farm lands will be more largely devoted to dairying in the future than in the past, though at one time, a few years since, the state held the foremost rank in the amount of creamery butter marketed.

The total land area of Iowa is 35,504,000 acres. Of this, according to the Twelfth Census Report

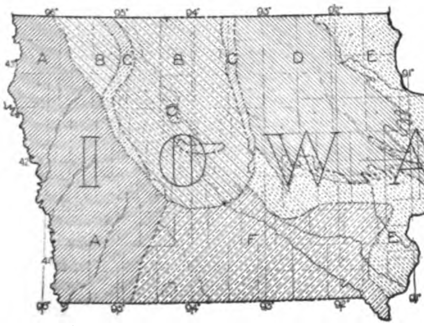


Fig. 67. Soil map of Iowa.—A, Missouri loess; B, Wisconsin drift; C, moraine; D, Iowan drift; E, Mississippi loess; F, southern Iowa loess.

(1900), 34,574,337 acres are in farms, 29,897,552 acres of which, or 86.5 per cent, are improved land. There were then 228,622 farms in the state. The total value of the farm property was $1,834,345,546. The total value of the farm products was $365,-411,528. The values of the leading products were: Domestic animals, $271,844,034; hay and forage, $30,042,246; dairy products, $27,516,870; cereals, $147,919,076.

The land grant college is separate from the State University and is located at Ames. The State University is at Iowa City. The federal Experiment Station is a part of the Agricultural College at Ames. There is a State Department of Agriculture with headquarters at Des Moines, in charge of the Secretary of Agriculture, who is elected by a Board of Directors, and they in turn elected by the delegates to the annual meeting. This Department has charge of the annual state fair, permanently located at Des Moines, and has supervisory relations with the state farmers' institute and the county agricultural fairs that receive aid from the state treasury. The State Board of Agriculture consists of eleven directors, one from each congressional district. The leading agricultural societies in this state are as follows: State Dairymen's Association, State Horticultural Society, Iowa Improved Stock-Breeders' Association, Corn-Breeders' Association, Swine-Breeders' Association, State Poultry Association, Sheep-Breeders' and Wool-Growers' Association, Corn-Belt Meat-Producers' Association and Agricultural Union.

NEBRASKA. (By *E. A. Burnett.*) Nebraska is almost exclusively an agricultural state. The wealth depends on the fertile soil and mild climate, and the industrious people. Within the last ten years the value of agricultural products in the state has more than doubled, reaching for the year 1905 approximately $250,000,000, or $200 per capita.

Geographically situated within the great plains area, it is approximately 400 miles long and 200 miles wide, and has an area of 76,840 square miles. Broadly speaking, the state is a gently rolling prairie with some rough broken land running into rugged buttes as the western and northwestern boundary is approached, with a rough district of sand-hills in the north-central part. The elevation of the Missouri river is approximately 1,000 feet above sea-level. This increases gradually until it approaches 5,000 feet at the Wyoming line. Rainfall decreases with increased elevation, from thirty-one inches annually at the eastern border to fifteen inches at the western border.

Grain-farming and live-stock form the two principal lines of industry. Fruit-growing, sugar-beet culture, grass and forage crops are of secondary importance. In eastern Nebraska corn is a great money crop. Winter wheat is extensively grown throughout eastern, central and southwestern Nebraska, and durum wheat, barley, and emmer in other farming sections. Oats are a staple crop. Forage crops are extensively grown, including large acreages of alfalfa and other tame grasses, and native hay meadows.

One hundred and fifty thousand tons of sugar-beets were produced in 1905. Two beet-sugar factories are in operation and a third is to be built in the North Platte valley.

Nebraska ranks high in the production of live-stock, large numbers being shipped or slaughtered each year. The dairy industry is developing rapidly. The annual revenue secured from its products is approximately $20,000,000, one-half of this being for butter sold. Approximately 1,000,000 sheep were fed for market in the year 1904. The state is fourth in the Union in the production of hogs, with approximately 3,000,000 head, January, 1905. Eastern Nebraska is the feed-lot of the range country lying farther west, a large proportion of the corn crop being fed on the farms to cattle, sheep and hogs, either home-grown or from the range country.

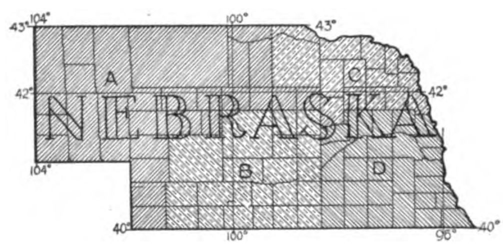


Fig. 68. Chief agricultural regions of Nebraska.—A, grazing, potatoes, hay, durum wheat and alfalfa in the valleys; B, corn, oats, heavy acreage of alfalfa, barley, winter wheat, cattle- and swine-feeding; C, corn, oats, wild hay, small acreage of alfalfa, cattle-feeding; D, fruit, corn, winter wheat, oats, fair acreage of alfalfa, cattle- and swine-feeding.

West of the 100th meridian the land is largely devoted to range pasture, supporting many thousand cattle and horses, much of this land being public domain. Since the Kinkaid law became operative in 1904, granting 640-acre homesteads, many thousand acres of this area have been settled by homesteaders.

Western Nebraska has a considerable area of land that needs to be irrigated and which will be developed either by private enterprise or by the national scheme of irrigation now in progress. With irrigation, this section of the state seems specially adapted to sugar-beet culture, small grain and alfalfa, and land has risen rapidly in value. The development of the agricultural resources of the state has been rapid for the last eight years, and will continue until the farms are broken up into smaller areas, assuring better care and attention to live-stock and better cultural methods in the production of crops.

Fig. 69. A farmstead in the Nebraska country.

Four trunk lines of railway traverse the state from east to west, and other lines enter the state. These railways center at Omaha, St. Joseph and Kansas City, furnishing excellent markets for live-stock and for general farm products. Omaha stands third as a packing-house city in the United States, and second as a sheep market. The Missouri river, acting as a basing point for freight rates, is favorable to the marketing of the farm products. Through rates from the Missouri river to the seaboard are also favorable.

The total land area of Nebraska is 49,177,600 acres. Of this, according to the Twelfth Census Report (1900), 29,911,779 acres are in farms, 18,-432,595 acres of which, or 61.6 per cent, are improved land. There were then 121,525 farms in the state. The total value of the farm property was $747,950,057. The total value of the farm products was $162,696,386. The values of the leading products were: Domestic animals, $142,769,629; hay and forage, $11,230,901; dairy products, $8,595,-408; cereals, $75,730,442.

The land grant college is one of the five colleges constituting the University of Nebraska. The federal Experiment Station is a part of the Industrial College in the University. There is a state substation at North Platte, founded in 1904. The farmers' institutes are operated by the University. There is no regularly established state department of agriculture outside of the State Board of Agriculture. The Governor is legally at the head of the dairy and food inspection, which is in charge of a commissioner as his assistant. The state veterinarian is also assistant to the Governor in charge of live-stock, sanitary and police regulations. The state fair is permanently located at Lincoln, in charge of the State Board of Agriculture. This Board consists of twenty-nine regular members serving two years, and of all presidents of county societies and all delegates, increasing the membership to between fifty and seventy. The leading agricultural societies in the state are as follows: State Board of Agriculture, Horticultural Society, Poultry Association, Dairymen's Association, Improved Live-stock-Breeders' Association, Shorthorn-Breeders' Association, Swine-Breeders' Association, Duroc-Jersey-Breeders' Association. Veterinary Medical Association, Corn-Improvers' Association, Park and Forestry Association, Bee-Keepers' Association.

KANSAS. (By *J. T. Willard.*) The four-hundred-mile stretch of Kansas from the Missouri valley on the northeast, with an altitude of 750 feet above sea-level, into the great plains on the west where an altitude of over 4,000 feet is attained, gives the state a diversity of climatic conditions that materially affects its agriculture. The rain-fall varies from forty inches per annum in the northeast corner to less than fifteen inches on the western border. Irrigation is practiced to a certain extent, chiefly in the Arkansas valley. The valleys of the Arkansas and Kansas rivers and of many of their tributaries are sandy, yet fertile; the uplands are usually clayey loam and very productive under proper tillage. Large areas in the southwest are extremely sandy, and vegetation is scanty.

The state has no navigable rivers, but has about 9,000 miles of railways, having excellent communications with Atlantic, Pacific, Gulf and Lake ports as well as with the interior. The principal market is Kansas City. Numerous milling establishments and packing-houses are located within the state.

Nearly all the staple crops are grown. In acreage and total production of corn and wheat the state ranks among the highest and is only less prominent in respect to oats, rye and barley. The wheat is principally hard winter, famous for flour production. Durum spring wheat is gaining in favor in the western part of the state. Ordinary spring wheats are but little grown because of poor results. The cultivated grasses and red clover are, in general, restricted to the eastern third of the state, though *Bromus inermis* promises to meet the need in parts farther west. Alfalfa, kafir corn and sorghum are very largely grown. The two latter are grown both for seed and roughage, and are highly esteemed in all parts of the state. All kinds of fruits do well on suitable soil in the eastern half of the state. Potatoes, sweet-potatoes and vegetables generally are grown with success. Other crops raised in sufficient quantities to be included in the statistics of the State Board of Agriculture are: Buckwheat, castor beans, cotton, flax, hemp, tobacco, broom-corn, millet, several tame grasses, and non-saccharine sorghums.

The region of greatest production of corn extends from the east line to the 100th meridian on the northern boundary and the 98th on the southern, approximately. The winter wheat belt crosses the state from north to south somewhat diagonally, lying between the 98th and 100th meridians on the north line and between the 97th and 99th meridians on the south line, though some counties of large production lie outside this area. Barley is most extensively grown west of 98 degrees 30 minutes longitude, but not in the southwestern counties. Oats are produced in largest quantities in the counties along the northern borderof the eastern half of the state, and in counties extending across the state between 96 degrees 30 minutes and 98 degrees 30 minutes and in certain ones in the southeastern part. Potatoes are grown most successfully in the northern counties from Phillips, in the central northeast, and in the river-bottoms of the Kansas and Arkansas. Certain areas of these river-bottoms are unexcelled for sweet-potatoes, and thousands of acres are devoted to their production.

Western Kansas is preëminently a grazing country, rough forage being grown for winter use. Range cattle are fattened in large numbers in the corn and alfalfa regions farther east. Dairying, poultry and eggs are important interests. Many swine and good horses and mules are produced. Climate, feed and markets are favorable to all kinds of stock-raising.

The future progress of the state will show a greater diversification of crops, more intelligent utilization of legumes in maintaining soil fertility and balancing feeding rations, more universal combination of one or more lines of animal husbandry with crop production, and intelligent adoption of systems of crop rotation accompanied by better tillage, especially with reference to moisture conservation in the western part of the state.

The total land area of Kansas is 52,288,000 acres. Of this, according to the Twelfth Census Report (1900), 41,662,970 acres are in farms, 25,040,550 acres of which, or 60.1 per cent, are improved land. There were then 173,098 farms in the state. The total value of the farm property was $864,100,286. The total value of the farm products was $209,895,542. The values of the leading products were: Domestic animals, $186,317,248; hay and forage, $18,499,287; dairy products, $11,782,902; cereals, $83,622,109.

The land grant college is the Kansas State Agricultural College, located at Manhattan. The Experiment Station is a department of this institution. A branch experiment station, having at its disposal over three thousand acres of land, is located on the abandoned Fort Hays Military Reservation in central Kansas. This is supported entirely by state appropriations. There is a State Board of Agriculture, which collects statistics and publishes agricultural matter of special value to farmers, part of this consisting of addresses given at an annual meeting. The Secretary of this Board is charged with the enforcement of the fertilizer law. Farmers' institutes are organized and assisted by the State Agricultural College. There are two organizations holding state fairs, one at Topeka, the other at Hutchinson. The leading horticultural and agricultural societies are: State Horticultural Society, State Board of Agriculture, Kansas Improved Stock-Breeders' Association, Kansas Swine-Breeders' Association, State Poultry Association, State Bee-Keepers' Association and Kansas Corn-Breeders' Association.

MISSOURI. (By *F. B. Mumford.*) The agricultural industries of Missouri are greatly diversified. The leading types of farming are breeding and feeding live-stock, grain-growing and orcharding. On most farms three types are practiced together, one or more of them being emphasized in order to conform to peculiarities of soil or climate or the tastes of the farmer. The state has been particularly famous for the production of fine cattle, saddle-horses and mules. The staple crop is corn, of which Missouri produced in one year one-eighth of the total product of the United States. There are many large farms, the largest of these comprising 30,000 acres.

The soils are deep and fertile, and high yields are common. The average annual rainfall is 39.05 inches. This rainfall is distributed throughout the growing season in a way highly favorable to the farmer. Excessive and long-continued droughts are very rare. The mean annual temperature is 54.3 degrees. Snow rarely falls before November 15 or later than April 15. The climate is therefore mild, humid and peculiarly favorable to the production of high-class domestic animals.

The state is divided into two great divisions,—the Ozark region in the south and the prairie region in the north. There are large areas of alluvium in the northwest and a smaller area in the southeast. A very rich deposit of brown loess extends from the extreme northwest corner of the state, parallel to the Missouri river, to the extreme eastern borders. Fertile black prairie soils are characteristic of the northwest-central part, while level prairie occupies a large district in the northeast.

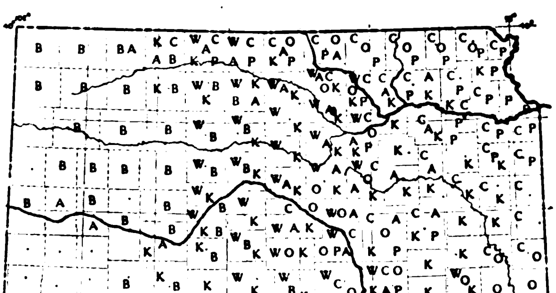


Fig. 70. Kansas, to show chief crop distribution.—A, counties which have grown over 5,000 acres of alfalfa per annum, in last seven years; B, those which have grown 1,000 acres of barley in same time; C, those which have grown 1,800,000 bushels of corn; K, those which have grown 5,000 acres of kafir corn; O, those which have grown 460,000 bushels of oats; P, those which have grown 80,000 bushels of potatoes (Irish); W, those which have grown 700,000 bushels of wheat.

The Ozark center is principally flinty, clay limestone of moderate fertility. The Ozark border is composed of a red limestone clay, moderately flinty and well adapted to the production of high-class fruit. The extreme southeast was swampy, but is now largely drained, and the alluvium thus rendered cultivable is very productive.

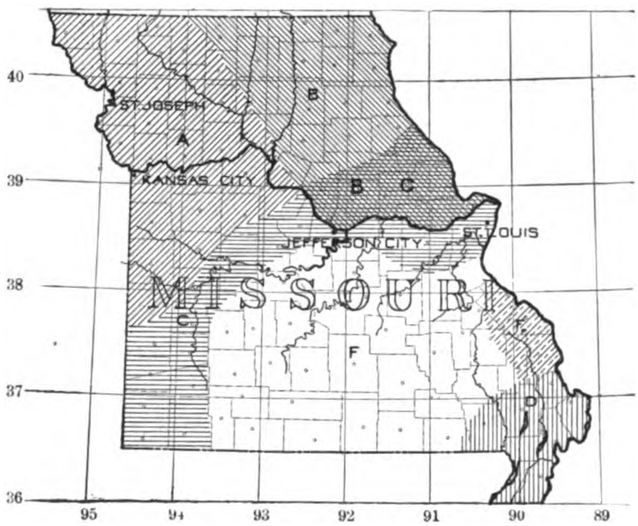


Fig. 71. General agricultural regions of Missouri.—A (black prairie), fertile corn lands, corn, hay, wheat, blue-grass, pasture, cattle, horses, hogs, mules; B (level prairie), corn, hay, blue-grass, pastures and wheat, cattle, hogs, horses and mules; C, largest wheat production; D, cotton, corn, alfalfa, cowpeas, watermelons; E, corn, wheat, cowpeas, watermelons; F (Ozark region), fruit lands.

The state is very favorably located with reference to several large cities, and the markets afforded by these centers of population insure unusually good prices for farm products. Numerous railroads and the great Mississippi and Missouri river systems provide excellent transportation facilities. The raising of some kind of live-stock will always be the greatest single agricultural industry of the state.

The total land area of Missouri is 43,990,400 acres. Of this, according to the Twelfth Census Report (1900), 33,997,873 acres are in farms, 22,900,043 acres of which, or 67.4 per cent, are improved land. There were then 284,886 farms in the state. The total value of the farm property was $1,033,121,897. The total value of the farm products was $219,296,970. The values of the leading products were: Domestic animals, $154,295,363; hay and forage, $20,467,501; dairy products, $15,042,360; cereals, $79,574,841.

The College of Agriculture and Mechanic Arts is a department of the State University, at Columbia. The Agricultural Experiment Station is a department of this college. The State Fruit Experiment Station is located at Mountain Grove. The State Board of Agriculture is composed of the dean of the Agricultural College and the Superintendent of Public Schools ex-officio, and of one member from each congressional district, appointed by the Governor. This Board appoints a salaried secretary, and has charge of farmers' institutes, control of infectious diseases among live-stock, and the enforcement of laws regulating the sale of imitation butter and skim-milk cheese. The Board of Agriculture is also a Board of Directors for the state fair, which is permanently located at Sedalia. The leading agricultural societies in the state are: Breeders of Improved Live-Stock, Swine-Breeders' Association, Sheep-Breeders' Association, Horse-Breeders' Association, Corn-Growers' Association, State Dairy Association, State Poultry Association, Missouri Horticultural Society, Grange, Farmers' Institute Societies.

9. UPPER CENTRAL, OR GREAT LAKES STATES

MICHIGAN. (By *C. D. Smith.*) The types of agriculture in Michigan are largely determined by location with reference to the great lakes, which divide the state into two peninsulas. The upper peninsula contains approximately two-fifths of the area, and is still covered with virgin forests, largely of maple, elm, cedar and spruce. Menominee county to the south, and Chippewa county at the extreme east are cleared and well settled. The proximity of the great mines affords a good market for all kinds of farm produce. The soil is a heavy clay and clay loam, with a large area of sand in the middle of the peninsula. The principal productions are garden vegetables, hay, especially clover, and in the southern part, sugar-beets and general farm crops.

In the southern peninsula the soil is glacial drift to the depth of twenty to a hundred and sixty feet. All types of soil prevail, from the heaviest clay in the southeastern part to the lightest sand in the northern central. The surface is gently undulating, with low hills and many lakes. The annual rainfall approximates thirty-two inches, well distributed throughout the season. General farming prevails, with large productions of butter, cheese, hay and potatoes. The special crops are peppermint on the muck lands in the west and southwest, furnishing one-third of the oil used in the world; celery on the muck lands in both peninsulas; sugar-beets supplying twelve factories in operation, with total slicing capacity of ten thousand tons daily; peaches along the western coast, yielding five thousand car-loads in the average season; apples over most of the southern part; flax for fiber in the eastern central part; potatoes in the northern and central parts; and tobacco in the southeastern part.

Owing to the proximity to the great cities and the network of steam roads and trolley lines, large areas are devoted to truck crops or to the production of milk for the city trade.

Although one-third of the farmers were born in

Canada or in some foreign country, as a class they own the farms which they operate, and carry forward the growing of crops in rotation—corn, oats, wheat and clover—except in the areas devoted to special crops. The growth of the common school system has kept pace with the increase in population, and much attention and money are expended on education. The growth of farmer organizations is especially noteworthy.

The total land area of Michigan is 36,755,200 acres. Of this, according to the Twelfth Census Report (1900), 17,561,698 acres are in farms, 11,799,250 acres of which, or 67.2 per cent, are improved land. There were then 203,261 farms in the state. The total value of the farm property was $690,355,734. The total value of the farm products was $146,547,681. The values of the leading products were: Domestic animals, $75,-997,051; hay and forage, $21,792,987; dairy products, $16,903,087; cereals, $41,819,042.

The land grant college of Michigan is the Agricultural College situated at Agricultural College. The federal Experiment Station is a department of it. There is no state department of agriculture. There is, however, a State Dairy and Food Commission, which looks after the creameries and cheese factories and city milk supplies in the state. The state fair is located permanently at Detroit, and is in charge of a State Fair Board incorporated under the name of the State Agricultural Society. It consists of a president, vice-president, secretary, treasurer, four former presidents, and twenty members of an executive committee. The leading agricultural societies in the state are as follows: State Dairymen's Association, Michigan Breeders of Improved Live-Stock, State Horticultural Society, State Swine-Breeders' Association, State Merino Sheep-Breeders' Association, State Shorthorn-Breeders' Association, State Association of Farmers' Clubs, State Millers' Association, State Bean-Growers' Association. The farmers' institutes are under the control of the State Board of Agriculture, in whose hands is placed the management of the Agriculture College. The Experiment Station has two branch stations, one at South Haven, in the southwestern fruit belt, and the other at Chatham, in the upper peninsula, both maintained by state funds.

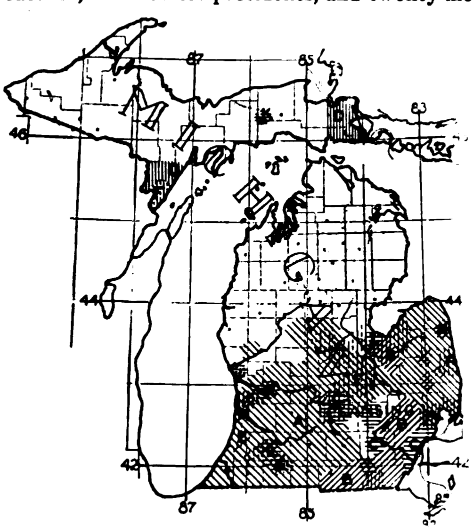


Fig. 72. Michigan, to show leading regions.—A, butter; B, cheese; C, milk; D, clover; E, peppermint; F, sugar-beets; H, flax; K, celery.

WISCONSIN. (By *A. R. Whitson.*) There are four chief types of agriculture followed in Wisconsin,—dairying, raising of potatoes and other truck-crops, tobacco-growing and general farming. The principal areas of these types are shown on the accompanying map. Their distribution is determined largely by the character of the soil, but in part also by the nationality of the people and the nearness to large markets and railroads.

Dairying is the chief industry on the clay loam soil of the southern and eastern part of the state. Special mention should be made of the Swiss cheese industry of Green county, in the central south.

Raising of potatoes and other truck-crops is chiefly followed on the sandy soils of the central part, and also to a considerable extent in the northwestern part of the state. It is in this region that the greater part of the potatoes raised for export are produced.

Tobacco is grown chiefly on the rich warm prairie-loam soils of Rock, Dane, Columbia, Vernon and Crawford counties, in the southwestern part of the state. The large product of these regions and less important areas of the state makes tobacco-raising one of the chief agricultural industries of Wisconsin.

General farming is, of course, practiced throughout the state, forming the chief basis from which the above-mentioned special lines have been developed, but it is followed especially in the newer sections of the originally timbered areas of the northern part of the state. The raising of sugar-beets, and of peas and corn for canning purposes, and of cranberries are important local industries. The large markets of Chicago and Milwaukee materially affect the agriculture of the southeastern part of the state.

The rapid rise in value of the improved agricultural lands is chiefly the result of large yields, following the careful methods of farm management practiced by the large German element of the population. Dairying is the chief agricultural industry, largely as the result of the encouragement and fostering care of the agriculture college, dairy societies, and the superior natural conditions of the soil and climate. The lands of the north-central section of the state will undoubtedly develop along dairy lines as a result of the excellent pasture and pure water which are characteristic of that region.

There are few states that have a greater variety of soil than Wisconsin. Physically, these embrace large areas of distinct sandy, humous and clay soils. The clay soils are residual from limestone in the southwestern section; glacial on limestone in the southeastern and eastern section, and glacial on crystalline rocks, chiefly granite, in the northern section.

The total land area of Wisconsin is 34,848,000 acres. Of this, according to the Twelfth Census Report (1900), 19,862,727 acres are in farms, 11,246,972 acres of which, or 56.6 per cent, are improved land. There were then 169,795 farms in the state. The total value of the farm property was $811,712,319. The total value of the farm products was

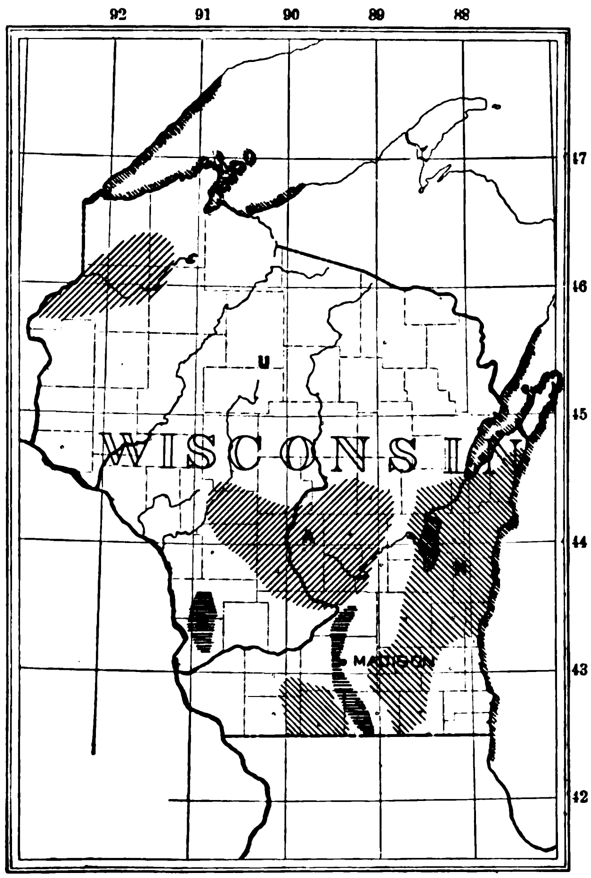


Fig. 73. Distribution of leading agricultural industries in Wisconsin. —A (upward shading to right), leading potato and truck regions; H (upward shading to left), principal dairy sections; B (horizontal shading), tobacco; U (not shaded), general farming. Dairying is rapidly developing in the central part of the state also. From the southeastern corner of the state milk is shipped to Milwaukee and Chicago and is supplied for condensing.

$157,445,713. The values of the leading products were: Domestic animals, $93,521,430; hay and forage, $19,267,709; dairy products, $26,779,721; cereals, $48,595,728.

The land grant institution of Wisconsin is the State University at Madison. The Experiment Station is a department of the College of Agriculture. The farmers' institutes are in the charge of the Board of Regents of the State University. There is a State Board of Agriculture consisting of one member from each congressional district, and two from the state-at-large, appointed by the Governor for three years. The state fair, located permanently at West Allis, near Milwaukee, is in charge of this Board. The agricultural organizations are: Dairymens' Association, Live-stock Breeders' Association, Growers' and Dealers' Tobacco Association, Agricultural Experiment Association, State Cranberry Association, State Horticultural Society, Swine-Breeders' Association, Cheese-Makers' Association, Butter-Makers' Association, Bee-Keepers' Association, Sheep-Breeders' Association, and various associations for special breeds of cattle and horses.

MINNESOTA. (By *Andrew Boss.*) There are three distinct types of agriculture in Minnesota. The first type may be termed diversified farming, including the production of grain, corn, grasses, fruits, vegetables, live-stock and dairy products. Grain-raising characterizes the second type and is followed extensively in certain sections. The third type supplies the large cities, Minneapolis, St. Paul and Duluth, with great quantities of fruits, potatoes and other vegetables; and, in the locality of each, trucking and dairy-farming are followed extensively.

The southern half of Minnesota is almost entirely given to diversified farming. Corn matures in all of this territory and the soil and climate are admirably suited to the production of the grasses and such cereals as wheat, oats and barley. The climate of the northwestern part of the state is not suitable to extensive corn-growing, and grain-raising clearly marks the type of agriculture followed. On much of the prairie land large quantities of wild hay are cut.

The local conditions surrounding the large cities are entirely responsible for the third type of farming.

The agriculture of the northeastern section is confined mainly to small farms or clearings in the forest areas of the state. Diversified crops, fruits, garden and dairy products are the staple products of this section.

The southern half of the state comprises rolling prairies and small timber belts. The soil is of glacial drift, warm, mellow, rich and admirably adapted to a variety of crops. The Red river region (the northwestern section) is a broad, flat valley, with a soil composed of alluvial silt, very rich and retentive of moisture, but requiring artificial drainage. Owing to lack of drainage and the short seasons, the soil is cold and not suited to raising such crops as corn. The northeastern part of the state has been heavily covered with pine and hardwood timber. The forests are rapidly becoming depleted, however, and the cut-over lands are being cleared and used for agricultural purposes. The soil in this section is a light loam well suited to the growth of vegetables and grasses. The rainfall over the whole state is abundant for crop production.

The great glacier and the Mississippi river have been important factors in forming the types of agriculture. The great water-power of the Falls of St. Anthony and the flour mills of Minneapolis were instrumental in developing markets for agricultural products. The river furnished the means of transportation before the era of railroads and even now is a factor in securing reasonable rates. The milling interests and the numerous railways have doubtless encouraged grain-raising and prolonged it beyond the point of profitableness. The farmers are industrious and progressive, and under the stimulus of better agricultural education are giving up the practice of exclusive grain-raising.

The future agriculture in Minnesota will be toward more intensive and diversified farming. The depletion of the forests in the northeastern section and drainage of the flat lands of the northwest will bring the northern half of the state into nearly as great agricultural productive capacity as the southern half. Grains, grasses, live-stock, dairy products, fruits and vegetables will gradually supplant the lumbering, mining and milling interests, and will retain for Minnesota the place it now holds among the foremost agricultural states.

The total land area of Minnesota is 50,691,200 acres. Of this, according to the Twelfth Census Report (1900), 26,248,498 acres are in farms, 18,442,585 acres of which, or 70.3 per cent, are improved land. There were then 154,659 farms in the state. The total value of the farm property was $788,684,642. The total value of the farm products was $161,217,-304. The values of the leading products were: Domestic animals, $86,620,643; hay and forage, $14,585,281; dairy products, $16,623,460; cereals, $85,817,555.

The land grant college of Minnesota, located at St. Anthony Park, is part of the State University, at Minneapolis. The federal Experiment Station is a department of the college, but located at St. Anthony Park. Two agricultural high schools as branches of the Agricultural College have been organized, one of which is located on the college farm, and in ten years has grown to have six hundred students. The other was recently established by the state legislature at Crookston, to accommodate the farm boys and girls of the several Red river valley counties in northwestern Minnesota. Well equipped sub-experiment stations are located at Crookston and Grand Rapids. The State Dairy and Food Commission, appointed by the Governor, is in charge of the pure food laws and creamery inspection work. The State Live-Stock Sanitary Board, also appointed by the Governor, is in charge of the police work relative to live-stock diseases. There is also a State Highway Commission, consisting of three members, appointed by the Governor, in charge of highway improvement. The annual state fair is held under the management of the State Agricultural Society, and is permanently located at Hamline. The Farmers' Institute is under a board known as the Institute

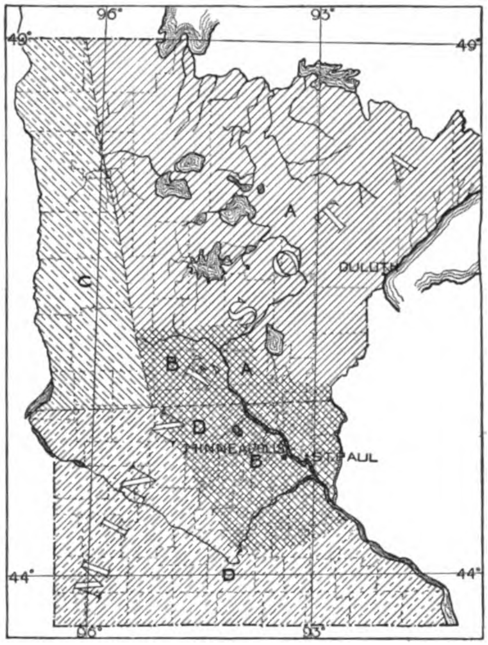


Fig. 74. Leading agricultural regions of Minnesota.—A (the pine land area), mineral deposits, fruit-growing, dairying, grasses and other forage crops; B (hardwood area), dairy-farming practicable; C (Red river valley), grains, grasses and other forage crops yield abundantly; D (rolling prairie), adapted to diversified farming, corn, grains and grasses successfully grown.

Board, composed of the presidents of the agricultural, horticultural and dairymen's associations, together with three members of the Board of Regents and the Governor of the state, ex-officio. The leading agricultural societies are as follows: State Horticultural Society, State Dairymen's Association, Live-stock Breeders' Association, Field Crop-Breeders' Association, Poultry Association, Good Roads Association, State Drainage Association, State Forestry Association and Farmers' Club.

10. NORTHERN PLAINS STATES AND PROVINCES

SOUTH DAKOTA. (By *J. W. Wilson.*) During the past few years South Dakota has made rapid progress along agricultural lines. This progress can be attributed to the large ingress of population from foreign countries and the Mississippi valley states. Only a few years ago it was classed as a prairie state where live-stock was brought in the spring, pastured on free range during the summer, and shipped to market in the fall. But today conditions are different. Through the efforts of the United States Department of Agriculture, in coöperation with the Experiment Station, numerous seeds of grains and grasses from foreign countries have been introduced and adapted to its conditions.

As to kinds of farming practiced, the state may be divided into two sections, with the Missouri river as a dividing line, although general farming is practiced in the Black Hills region to a considerable extent. In the eastern section diversified farming is practiced nearly exclusively. With the exception of corn, all crops that can be grown in the corn-belt can be raised here. In the northern part of this section it is problematical whether the larger dent corns can be considered a safe crop, owing to the cool nights and short growing season. However, the southern part of the state east of the Missouri river may be considered safely in the dent-corn belt. In the western part of this eastern section, much of the land is still in native prairie, but is rapidly being divided into farms of quarters, halves and sections.

The area west of the Missouri is used principally for grazing purposes. But new lines of railways are under construction, the government land is being rapidly taken, and there is no question but that this section will be much more densely peopled than at present.

South Dakota has a soil so rich that no commercial fertilizers will be needed for years to come. There is an abundance of good water at a moderate depth, and there are extensive artesian well basins east of the Missouri river. Owing to the large area, the climatic conditions vary considerably in different parts of the state; but, where there is sufficient rainfall, good crops are produced. Good facilities are provided for reaching market. The greatest need of the state today is more people to improve the lands by intelligent tillage.

The greatest industry is that of raising live-stock. The quality is being improved as numerous herds of full-bloods are established in each county, especially in the eastern section.

As for the future, with the high-priced lands in the great corn-belt states, with the effort that is being made by the federal government to make productive large tracts of lands in the semi-arid regions, and with the introduction of animals and grains of the best types in the world, South Dakota must be considered as one of the most promising agricultural states in the Union.

The total land area of South Dakota is 49,184,000 acres. Of this, according to the Twelfth Census 19,070,616 acres are in farms, 11,285,983 acres

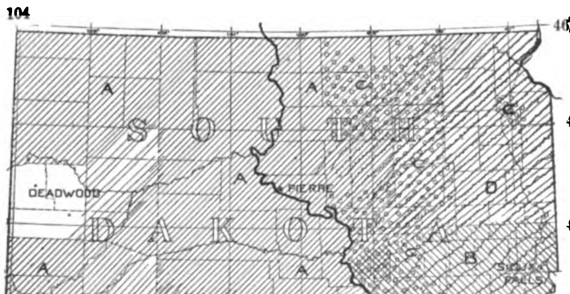


Fig. 75. Agricultural regions of South Dakota.—A (oblique shading to right), grazing; B (to left), corn; D (wavy shading), general mixed-farming; C (small circles), artesian wells region.

of which, or 59.2 per cent, are improved. There were 52,622 farms in the state. The total value of the farm property was $297,525,302. The total value of the farm products was $66,082,-419. The values of the leading products were: Domestic animals, $64,287,578; hay and forage, $5,954,229; dairy products, $4,351,568; cereals, $34,506,061.

The land grant college of South Dakota is located at Brookings, known as the South Dakota Agricul-

Fig. 76. Barns, sheds and feed-lots on an Angus breeding farm in corn-belt of the Missouri valley country.

tural College. The Hatch Experiment Station, by law, is made a part of the College. There is a State Board of Agriculture appointed by the Governor; the principal duty this Board performs is to have charge of the state fair, which is held in Huron annually on permanent grounds. All vacancies on this Board are filled by direct appointment of the Governor. The state has farmers' institutes conducted by a board consisting of the Regent's Committee for the Agricultural College and the president of the Agricultural College. The principal agricultural societies are: The South Dakota Improved Live-Stock and Poultry-Breeders' Association, the South Dakota Swine-Breeders' Association, the South Dakota Wool-Growers' Association, the South Dakota Poultry and Pet Stock Association, the South Dakota Dairymen's Association, the South Dakota Shorthorn-Breeders' Association, the South Dakota Hereford-Breeders' Association and the South Dakota State Horticultural Society.

NORTH DAKOTA. (By *J. H. Shepperd.*) The agriculture of North Dakota represents four types: Grain-farming; mixed grain-farming and stock-raising; dairy-farming; and mixed-farming, with ranching predominating.

The Red river valley, long the famous grain-growing district, is now changing to mixed-farming. Small but constantly increasing numbers of live-stock are being produced annually without reducing the yearly output of grain. The vast native fertility of the region particularly fits it for grain production. With the advent of mixed-farming, medium-sized and small farms are gradually replacing the bonanza enterprises.

The district indicated as a mixed-farming region depends on small grain as the chief money product; while the crops of this section constitute the chief income, they are strongly supplemented by the income from the sale of live-stock. The land in this section is somewhat undulating. While it is mostly tillable, there is a small percentage that must be grazed to realize an income from it. In the farming districts of the state, flax flourishes unusually well and is frequently a better money-maker than wheat. Barley also proves a profitable crop and is largely produced.

Strains of Indian corn have been bred to suit this region, and they are grown as a rotation crop with small grain. Changing from small grain to corn proves a great advantage since it stimulates the production of small grain crops, while the corn produced carries large numbers of live-stock, which add to the income and also to the fertility of the land. The market for vegetables, other than potatoes, is confined to the local demand of the few small cities of the state.

The region designated on the map as engaged in dairy-farming produces a large quantity of small grain annually, and has been unusually successful in the production of durum wheat. There are many successful creameries in this section. Dairying seems to be spreading into the newer districts and is probably destined to take a prominent part in the future development of the state.

The stock-raising or ranching district is now confined to the rough and broken region known as the "bad lands," where the grass cures on the prairie in nutritious form and constitutes a provender that will nourish animals during the autumn and winter as well as in the spring and summer. The change in North Dakota is unquestionably toward mixed-farming and more intensive and painstaking methods.

The total land area of North Dakota is 44,924,800 acres. Of this, according to the Twelfth Census Report (1900), 15,542,640 acres are in farms, 9,644,520 acres of which, or 62.1 per cent, are improved land. There were then 45,332 farms in the state. The total value of the farm property was $255,266,751. The total value of the farm products was $64,252,494. The values of the leading products were: Domestic animals, $41,951,659; hay and forage, $5,182,917; dairy products, $2,853,133; cereals, $40,126,051.

The land grant college of North Dakota is located at Fargo, known as the North Dakota Agricultural College. The federal Experiment Station is a department of it. There are two branch experiment stations supported by the state, one of which is located at Edgeley and the other at Dickinson. There is a State Department of Agriculture, with headquarters at Bismarck, in charge of the Commissioner of Agriculture and Labor, who is elected for a two-year term. This Department has charge of the state statistics, the legal registering of brands, and licensing of live-stock used for breeding purposes, and, at intervals, is required to gather data showing the advantages that the state offers to prospective settlers. The farmers' institutes are placed in charge of a governing board consisting of the president of the board of trustees, president of the college, professor of agriculture and professor of dairying of the agricultural college, and the Commissioner of Agriculture and Labor. The state fair is held at Grand Forks on the odd-numbered years and at Fargo on the even-numbered years. The leading agricultural societies of the state are the North Dakota Live-Stock Association, Grain-Growers' Association, Horticultural Society, Dairy Society and State Poultry Association.

MANITOBA. (By *W. J. Black.*) In the province of Manitoba grain-growing is the most important type of agriculture. In 1905, 2,643,588 acres of wheat were grown, yielding an average of 21.07 bushels per acre; oats, 1,031,239 acres were grown, yielding an average of 42.6 bushels per acre; barley, 432,298 acres, yielding 34.2 bushels per acre. Of all the other grains, including flax, rye and peas, about 34,000 acres were grown. In some sections dairying is practiced; it has not yet become one of the most important industries, but the local market for dairy products is growing rapidly and there is reason to expect that the dairy business will develop steadily. In all parts of the province, live-stock-raising is conducted to some extent and a large number of cattle are shipped to the British market.

All parts of the province, except certain undrained areas, have been found well adapted to grain-growing. Many districts without good natural drainage have had large drains put in by the government, and land-owners in turn have had similar drains directed to the main channels. The result of this is that much land that was previously considered unfit for cultivation is proving very valuable, both for grain-growing and mixed-farming. The soils of the province vary from heavy clay to sandy loam, yet little difference has been found in the average yield of wheat on the different kinds from year to year.

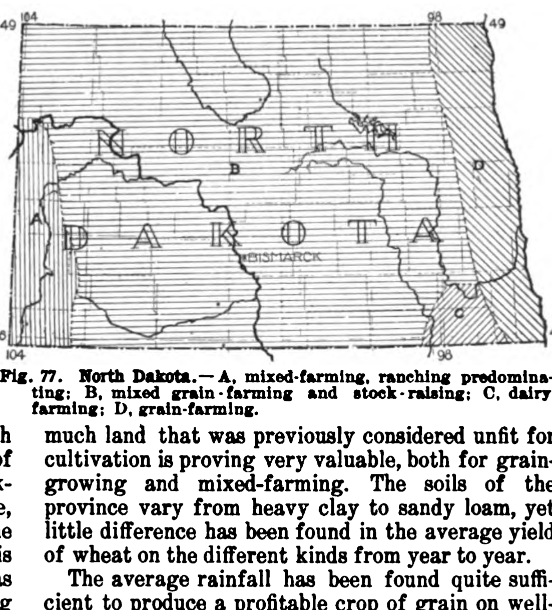


Fig. 77. North Dakota.—A, mixed-farming, ranching predominating; B, mixed grain-farming and stock-raising; C, dairy-farming; D, grain-farming.

The average rainfall has been found quite sufficient to produce a profitable crop of grain on well-tilled soil.

During the last few years the country has become traversed by a network of railways, until it is safe to say that the average farmer in the principal agricultural districts of the province is not more than six miles from a railway. Markets for farm produce are therefore within easy reach.

The population of Manitoba may be said to be cosmopolitan in the highest sense. The older districts are peopled very largely by settlers from eastern Canada and United States and Great Britain. During

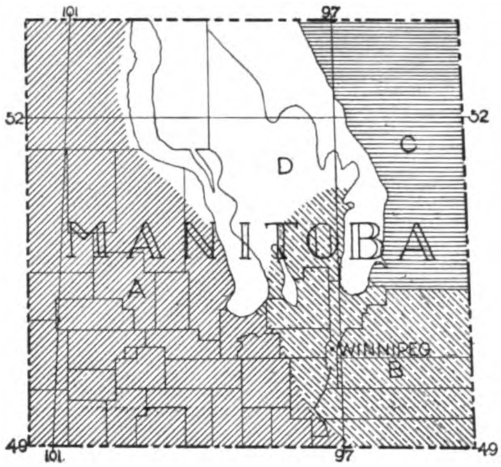


Fig. 78. Main agricultural parts of Manitoba.—A, wheat-raising and mixed-farming; B, grain-raising and dairying; C, timber; D, undeveloped, adapted to farming.

recent years, a large number of settlers have come from Iceland, Norway and Sweden, Germany, France and Austria, and it is gratifying to know that all have become assimilated into one homogeneous population.

In regard to the future agriculture of Manitoba, there is little doubt but that it will develop in the direction of more mixed-farming. There is a tendency on the part of farmers to raise more stock and develop the home dairy, and depend less on wheat as a money-maker.

The total land area of Manitoba is 47,331,840 acres. The number of acres in farms is 5,500,000, practically all of which may be considered improved land. There are approximately 46,000 farms in the province. The total value of the farm property is now approximately $200,000,000 and is increasing rapidly. The total value of the farm products for 1905 is estimated at $81,115,000.

There is an agricultural college now being established near the city of Winnipeg. Connected with this, are 117 acres of land, a large part of which will be used for demonstration purposes. At the city of Brandon there is an experimental, or test farm, which has been in operation for twenty years. This institution is under the control of the Dominion Government. The Department of Agriculture controls the agricultural societies and farmers' institutes of the province, and supports them annually by means of financial grants. There are at present fifty agricultural societies and twelve farmers' institutes. The only difference between these two kinds of organizations is that the agricultural societies each year hold an exhibition of live-stock and agricultural produce, for which substantial prizes are given. There are also four agricultural and arts associations, whose chief function is to hold exhibitions. One of these, the Winnipeg Agriculture and Arts Association, holds a show each year that corresponds with the state fairs held in various states of the Union. These fairs are also held at Brandon, Neepawa and Killarney. There is a Provincial Live-stock Association, Provincial Dairy Association, Provincial Horticultural Association, Provincial Bee-Keepers' Association and a Provincial Poultry Association.

SASKATCHEWAN. (By *J. R. C. Honeyman.*) The characteristic type of farming in the province of Saskatchewan at present is the growing of grain, chiefly wheat, for export. In some districts especially suited to the purpose, mixed-farming is followed, while in others cattle-ranching on a considerable scale is the chief industry. The following are the official figures of grain production, acreage and yield per acre for 1904: Wheat—bushels, 14,674,730; acreage, 910,359; yield per acre, 16.11 bushels. Oats—bushels, 10,756,350; acreage, 346,530; yield per acre, 31.04 bushels. Barley—bushels, 598,336; acreage, 24,650; yield per acre, 24.47 bushels. Flax—bushels, 166,384; acreage, 15,917; yield per acre, 10.45 bushels.

The province includes an area of 250,119 square miles, of which 6,629 square miles is water surface. Only about one-half of this area—the southern part—is under settlement. This forms the major part of the second great prairie steppe of Canada. It consists largely of level prairie. The intracontinental position of the province and its high

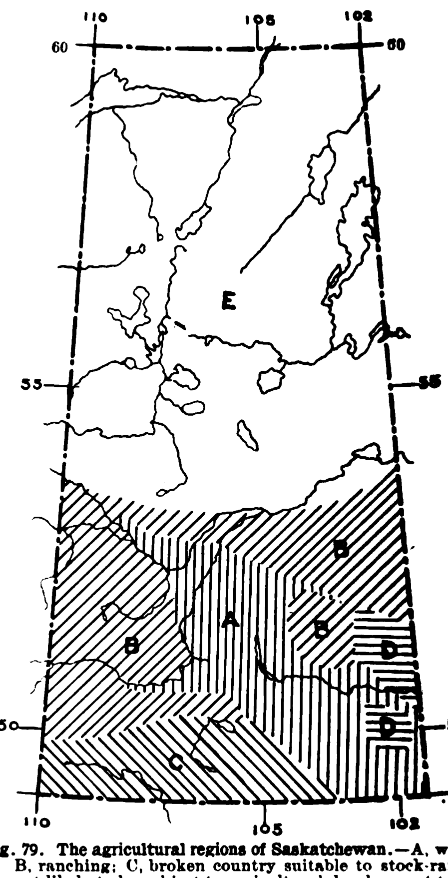


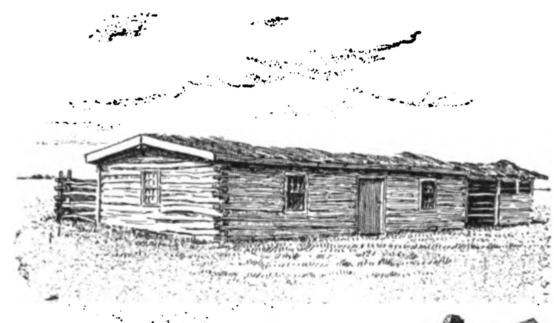
Fig. 79. The agricultural regions of Saskatchewan.—A, wheat; B, ranching; C, broken country suitable to stock-raising, not likely to be subject to agricultural development to any extent; D, country eminently adapted to mixed-farming; E, unexplored (new province, established 1905).

Plate IV. A new town in the western farming country. Typical shipping point in the wheat district of the Canadian Northwest. Lumsden, Saskatchewan

elevation above sea-level have an important influence on its climate, especially in limiting the rainfall, which, however, proves ample for the production of the finest crops, which ripen early and satisfactorily because of the abundant sunshine. The average annual rainfall is about seventeen inches.

The severity of the winters is such as to preclude, as a rule, the possibility of agricultural operations from November to March.

The soil varies in character according to locality, but, in general, it may be said to consist of a top soil of rich sandy loam, with clay or sandy subsoil. In certain districts, such as near Regina, the soil is a heavy clay loam of great depth, which does not bake and crack. The soils of the province seem to bear a large amount of continuous cropping without apparent loss of fertility.



The problems of transportation are rapidly being solved by the construction of lines of railroad running in all directions. There are 1,886 miles of railroad in actual operation, providing adequate outlet for the chief product of the country—wheat. The chief source of increase of population at the present time, is immigration, principally from European countries and the United States.

The general tendency of agriculture will undoubtedly be toward greater diversification, smaller farms and these better cultivated. So long as new land of first quality is being opened for settlement, the production of wheat in large quantities will be the chief object of the farmer in the newer districts; but, with the exhaustion of soil fertility, the increase of weeds, and the opening of new markets such as by the growth of towns, and the formation of an industrial population, other things will be found more profitable than wheat, though, owing to the peculiar properties of that cereal as grown in the province, there must always be a steady demand for it so long as its present high standard of excellency is maintained.

The total land area of Saskatchewan is 156,133,120 acres. There are about 1,500,000 acres of improved land in the province. The chief source of income is wheat, the value of this crop for 1905 being, approximately, $29,000,000.

There is no agricultural college at present in the province. The only experiment station is situated at Indian Head, under the control of the Dominion Department of Agriculture. There is a Provincial Department of Agriculture, with headquarters at Regina. Its functions are to administer the laws respecting agricultural matters and public health, to institute inquiries, to collect facts and statistics relating to agricultural, manufacturing or other interests of the province and to adopt measures for circulating and disseminating the same. There are no farmers' institutes, but institute work is conducted by the agricultural societies of the province under the direction of the Department. There is as yet no provincial fair, but local shows are held under the auspices of the various agricultural societies. There are thirty-two agricultural societies in the province, of about equal importance. Those having the largest membership are as follows: Maple Creek, Regina, South Qu'Appelle, Yorkton, Saltcoats, Fairmede and Carrot River.

ALBERTA. (By *C. W. Peterson.*) The province of Alberta, the great stock-raising, dairy-farming, agricultural and mineral country, embraces an area larger than that of England, Ireland and Scotland combined. But little was known or heard of the country until the advent of the Canadian Pacific Railway in 1883. Since then steady progress has been made in developing the ranching and mineral interests. Up to 1883, Alberta had no direct communication with Manitoba or eastern Canada. The postal service was through the United States and American money was in circulation.

With a length of some 350 miles from east to west and 800 miles from north to south, the province includes in its 275,000 square miles every variety of forest and stream, grazing and agricultural lands, minerals and oil. In it are found some 45,000,000 acres of very fertile soil and some of the largest and best deposits of coal, metals and petroleum on the continent.

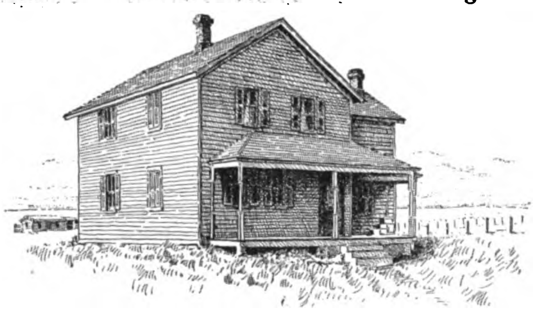


Fig. 80. In the West. From the old home to the new.

The district may roughly be divided into two great sections—northern Alberta, which embraces all that part lying north of Township Thirty-five, and southern Alberta, comprising the remainder. Northern Alberta is especially adapted to mixed-farming, with stock-raising as an adjunct, while southern Alberta is at present chiefly devoted to winter wheat production and stock-raising. Considerable mixed-farming is, however, also conducted under irrigation in some localities.

Within the borders of northern Alberta is a great area of fertile land, well timbered and well watered. The climate is good. The soil consists of a layer of one to three feet of black vegetable-mold, with

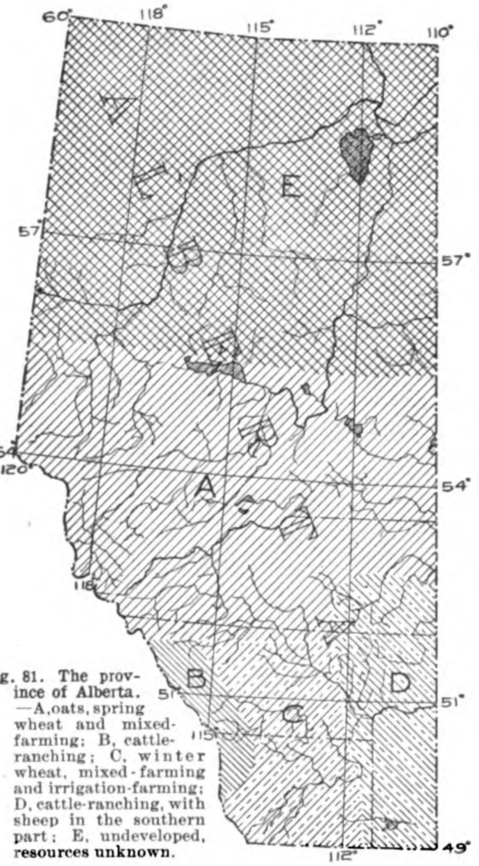


Fig. 81. The province of Alberta. —A, oats, spring wheat and mixed-farming; B, cattle-ranching; C, winter wheat, mixed-farming and irrigation-farming; D, cattle-ranching, with sheep in the southern part; E, undeveloped, resources unknown.

little or no admixture of sand or gravel. It is peculiar to this section of the country that the black mold is deeper on the knolls and ridges than in the hollows. Large yields of oats, barley and wheat are common. Live-stock of all kinds is raised extensively, including horses of all grades, from heavy draft to Indian ponies, cattle, sheep, pigs and poultry. Horses do well without stabling all the year round.

The plateau of southern Alberta is the country of the great winter wheat farms and cattle and horse ranches, the finest region for stock-raising on the whole continent, carpeted, as it is, over all its extent with thick and luxuriant grasses. The whole region is marked by an equable temperature, with freedom from rapid and extreme fluctuations in the growing season. Range stock needs little or no shelter. The soil is fertile and deep, varying from a rich sand to clay loam, and is adapted to the growing of all classes of cereals, grasses and vegetables.

The variety of winter wheat most extensively grown is Kansas Turkey Red (Alberta Red). This hard wheat requires, for best production, a soil rich in nitrogen and receiving a limited quantity of moisture, combined with a short growing season and a dry atmosphere. Central and southern Alberta possess these characteristics. There is an enormous market for flour and wheat in oriental countries, with which Calgary has direct connection.

One of the most stupendous irrigation undertakings of modern times is at present nearing completion immediately east of and contiguous to Calgary. It is expected that about 1,500,000 acres of land can be irrigated, at an ultimate cost of between four and five million dollars.

The agricultural administration is in the hands of a Department of Agriculture of the local government, with a responsible minister at its head. Several experimental stations are soon to be established, with at least one under irrigation. Live-stock associations, with headquarters at Calgary, are established. The Provincial Fat-Stock Show is also held at Calgary.

11. ROCKY MOUNTAIN STATES

MONTANA. (By *F. B. Linfield.*) It has been only within the past ten to twenty years that agriculture has been considered a factor in the development of Montana, and probably ten years will cover the time of the recognition of the possible agricultural development. The state has been, and will continue to be, a mining, grazing and agricultural state; but it is to the agricultural industry that it must look for its greatest increase in population and wealth.

Montana is one of the best watered of the arid states. The Clark's Fork of the Columbia, the Upper Missouri and the Yellowstone rivers, with their tributaries, carry large amounts of water, and flow in the state for considerable distances. Along these rivers and their tributaries are found millions of acres of fertile lands, much of which will in time be irrigated.

In view of the above facts, the agriculture of the state is, first, pastoral; the higher plateaus and valleys and the rolling hills furnish a large annual crop of cattle, sheep and wool. Very large areas of the level plateaus, which are a great distance from a water-supply, will be farmed without irrigation.

In the fertile valleys along the rivers, irrigation is practiced, and all kinds of grains except corn yield abundantly. Wheat, oats, barley, peas and beans are all grown. Of fodder crops, alfalfa, red and alsike clover grow well, yielding from two to three crops during the season. Timothy is also a very successful crop and finds a ready market at a good price in the mining towns. Roots and potatoes yield large and profitable crops.

In the Bitter Root and the Flathead valleys, in the northwest, and the Yellowstone valley in the southeast, all the hardier apples do well and small-fruits yield abundantly. In the other valleys, fruit will be raised chiefly for home consumption.

The Rocky Mountains and the chinook winds have a very important effect on the climate and agriculture of Montana. In the valleys west of the range the climate is equable and mild even up to the Canadian line, and fruit-raising is a growing industry. The short season alone excludes the later-ripening varieties of fruits.

East of the Rocky Mountains, and extending for 250 to 300 miles, the chinook winds materially modify the climate, producing less extremes both in winter and summer. Grain and fodder crops are here the staples, and on this foundation will be built a large live-stock industry.

The plains country and "bad lands" in the eastern part of the state, extending about 200 miles west from the Dakota line, are affected little, if any, by the chinook winds, and here the extremes of heat and cold are greater. Dakota corn is here a possible crop.

The market for most of the Montana farm products is local, in the mining towns. A small quantity of grain is shipped out of the state, but the range furnishes the larger part of the exports of the state. Cattle, sheep and wool bring yearly to the farmers and stockmen from $15,000,000 to $20,000,000.

The farm and the range business are becoming amalgamated. The farm provides the winter feed for the range stock. This arrangement will provide a market for the surplus range stock that will be fattened for eastern consumption.

The total land area of Montana is 92,998,400 acres. Of this, according to the Twelfth Census Report (1900), 11,844,454 acres are in farms, 1,736,701 acres of which, or 14.7 per cent, are improved land. There were then 13,370 farms in the state. The total value of the farm property was $117,859,823. The total value of the farm products was $28,616,957. The values of the leading products were: Domestic animals, $51,724,113; hay and forage, $5,974,850; dairy products, $1,669,978; cereals, $3,267,726.

The Montana Agricultural College, established at Bozeman in 1893, is the land grant institution of the state. The federal Experiment Station is a department of it. There are no permanent sub-

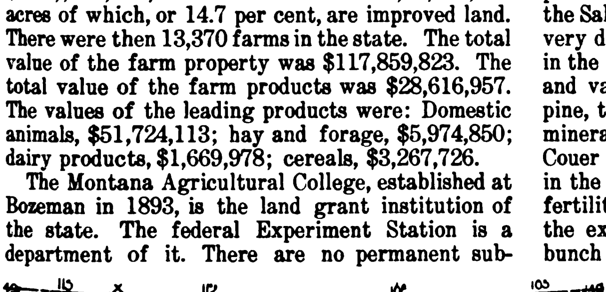


Fig. 82. Leading agricultural regions of Montana.—A, fodder, grain and fruit; B, grain, clover and alfalfa; C, farming without irrigation, hay and fruit; D, alfalfa, grain and fruit; E, grain, hay and vegetables. Unmarked areas west of line X X, in forest and range pasture; east of line X X, range pasture.

stations, but work on soil cultivation and crop growth is conducted at several temporary stations. The State Bureau of Agriculture, Labor and Industry is a statistical bureau and has no executive power. The farmers' institute work is under the control of a State Board of Farmers' Institutes, of which the director of the experiment station is a member. The state fair is located permanently at Helena, and is under the control of a Board of Directors consisting of one member from each county in the state, appointed by the county commissioners. The leading

Fig. 83. Getting a start. Cabin of a settler from Chicago in Milk river valley, Montana.

agricultural societies of the state are: Montana Stock-Growers' Association, Montana Registered Cattle-Breeders' Association, Montana Wool-Growers' Association, Montana State Horticultural Society, Montana State Agricultural Society.

IDAHO. (By *L. F. Henderson.*) The elevated plateau and mountain ranges at the headwaters of the Salmon and Payette rivers divide Idaho into two very distinct regions. That north of this divide is, in the main, a heavily timbered area, with extensive and valuable forests of white pine, cedar, yellow pine, tamarack, spruce and firs. It is also a great mineral region, the silver and lead mines of the Couer d' Alenes in the northeast being the richest in the world. The river-bottoms are of unexcelled fertility. Many prairies exist in this section, while the extensive Palouse country, once covered with bunch grass, is now occupied by almost continuous grain fields and orchards. The elevation here is from 2,000 to 3,000 feet above sea level. The soil is a rich, dark loess. The grains and all the fruits common to the temperate zone grow to great perfection. Many of the prairies are more adapted to cattle-raising than to cropping, though there is no place suitable to either where these two industries are not pursued. The most important kinds of live-stock in this section are cattle, hogs and horses; while the apple, prune, pear, wheat, oats and barley are the most marketable crop products. In the valleys of the Snake, Clearwater and Potlatch rivers, in the west and south, a very warm, dry and sunny summer renders irrigation necessary in restricted districts—a practice that is not essential in the other parts of northern Idaho. Amongst the crops which do well here may be mentioned the European grape, English walnuts, peaches, apricots, almonds and melons of all kinds. The climate is delightful, hot nights being almost unknown. The winters and early springs, owing to the alternations of snow and rain, are not ordinarily pleasant, but the fertility and enormous crops of this country are dependent on this very fact, since irrigation is not practiced except in a few sections, and would be impossible even were it necessary.

The country south of the Payette Lakes, in the central part of the state, constitutes the second region. This section, though raising many of the same products as the northern one, differs from it widely in its physical features. While cut by many high mountain ranges in almost every direction, it may be called the country of sage plains. Irrigation is necessary in almost every district where agriculture is practiced. The high plateaus and mountain ranges are of great mineral value, present as well as potential, and are grazed by almost untold thousands of cattle and sheep. Quantities of alfalfa, with other hay and grain, furnish food for these flocks through the short and ordinarily pleasant winters. The fruit of this region, especially its winter apples, pears and prunes, is of the first quality. Vast irrigation ditches cut this country in every direction. These are, in the main, private enterprises, but the general government is entering the field with its reclamation service and conserving by gigantic reservoirs the waste waters that are lost during the melting of the snows. In a few years, the desert region of southern Idaho will be a thing of the past.

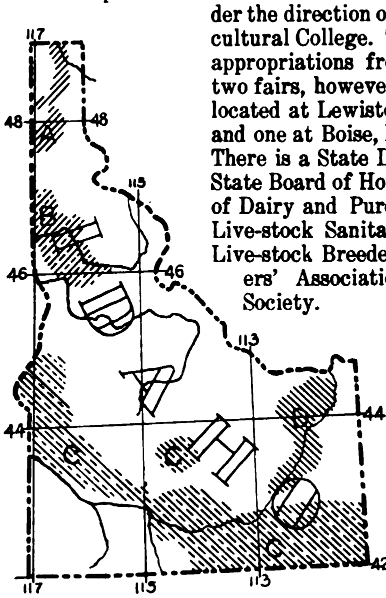


Fig. 84. Idaho, to show leading agricultural regions.—A, agricultural land, no irrigation except near Rathdrum; B, agricultural land, little irrigation; C, agricultural land and grazing, irrigated; D, agricultural land, irrigated.

The total land area of Idaho is 53,945,600 acres. Of this, according to the Twelfth Census Report (1900), 3,204,903 acres are in farms, 1,413,118 acres of which, or 44.1 per cent, are improved land. There were then 17,471 farms in the state. The total value of the farm property was $67,271,202. The total value of the farm products was $18,051,625. The values of the leading products were: Domestic animals, $21,389,853; hay and forage, $4,238,993; dairy products, $1,243,197; cereals, $3,212,387.

The land grant college of Idaho is a part of the University at Moscow, and the federal Experiment Station is a department of the College of Agriculture. There is no state department of agriculture, the Commissioner of Immigration doing a great deal of the work of such a department. The Commissioner is appointed by the Governor and resides at Boise. Farmers' institutes are conducted under the direction of the Experiment Station and Agricultural College. There is no state fair supported by appropriations from the state treasury. There are two fairs, however, under private management, one located at Lewiston, known as the Inter-state Fair, and one at Boise, known as the Inter-Mountain Fair. There is a State Dairy and Pure Food Association, State Board of Horticultural Inspection, State Board of Dairy and Pure Food Commissioners and a State Live-stock Sanitary Board. There is also a State Live-stock Breeders' Association, Idaho Wool-Growers' Association, and a State Horticultural Society.

WYOMING. (By *B. C. Buffum.*) The agriculture of Wyoming is, perhaps, as new and undeveloped as that of any part of the United States. Situated in the inter-mountain section of the arid region, there are high plateaus of comparatively level land and lower valleys along the larger water courses where considerable areas are being developed by the establishment of irrigated farms and ranches. Two-thirds of the production of these lands is native hay for winter stock food. It is estimated that there is sufficient water-supply to reclaim, by irrigation, about 10,000,000 acres. There are approximately 2,000,000 acres now under ditch and the work is being rapidly advanced. There are about 20,000,000 acres of mountain area, about one-half of this being covered with timber. The remaining half of the state is classed as grazing land, but considerable areas of this land will eventually be cultivated by systems of so-called "dry-farming," as has already been done in the eastern and northern regions,—the raising of drought-resistant crops without irrigation by advanced methods of management.

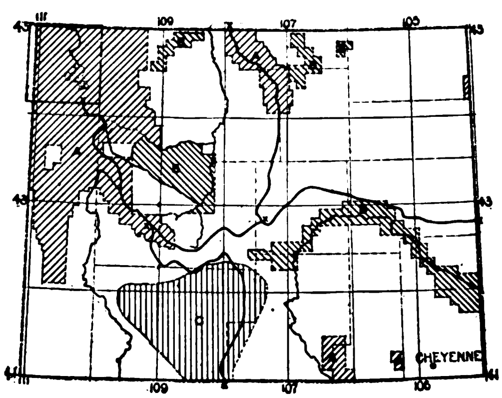


Fig. 85. Wyoming.—A, forest reservation; B, reclamation land; C, desert (winter range). All other areas are used for farming, ranching and grazing. Heavy lines, X X, mark irrigation divisions.

The region in the southwestern part of the state is known as the "red desert," and, while a truly desert area, it now supports more than 2,000,000 sheep. The range stock business is, however, rapidly giving way to more permanent farm homes. Mixed-husbandry, in which the diminished range can be profitably used in connection with the cultivated lands, will be the characteristic agriculture. Some regions are suitable to pure farming for the production of grains, potatoes, fruits and sugar-beets for factories.

The mean annual temperature of the state is about forty-four degrees. The rainfall averages from ten to twelve inches per annum in the agricultural sections and the climate is characterized by dry air and abundant sunshine, with little winter snow and few destructive storms.

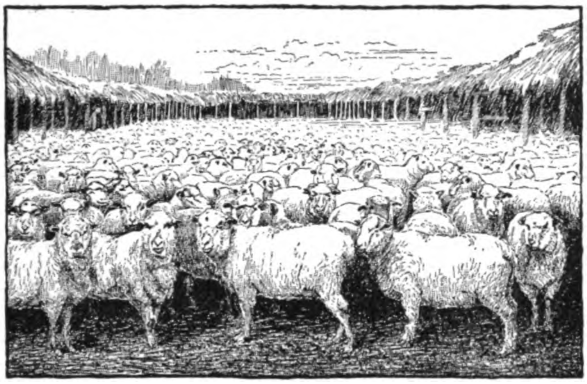


Fig. 86. A sheep corral in the great West.

The state is divided into four irrigation divisions, as indicated on the map. Water Division No. 1, in the southeastern corner, includes the drainage area of the North Platte river and its tributaries. Here are extensive areas that are well watered and on which are being produced the finest quality of small grains, alfalfa, potatoes, flax and field-peas. Water Division No. 2 covers the drainage area of the Powder and Little Missouri rivers in the northeastern section of the state. Both irrigation and dry-farming are here practiced. Water Division No. 3 includes the drainage area of the Bighorn river and its tributaries. This region is suitable for the production of apples, pears, cherries and other hardy fruits. Here great activity is going on in agricultural development with the building of railroads, great irrigation canals and the opening to settlement on August 15, 1906, of a part of the Wind River Indian Reservation. Water Division No. 4, along the Green, Snake and Bear rivers, is largely covered with forest reserves and grazing areas. There are some areas of agricultural lands along the above streams which are being developed.

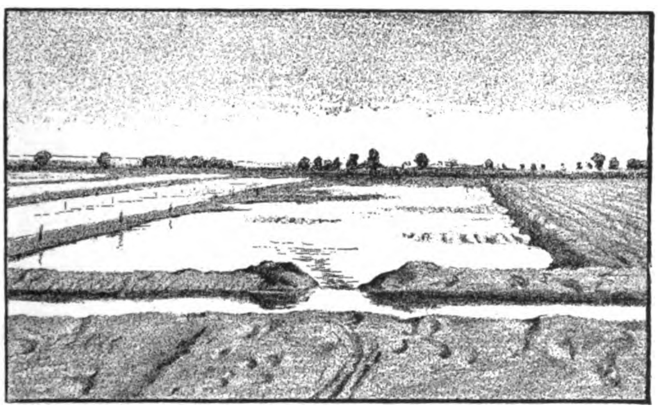


Fig. 87. Irrigation by flooding.

With the exception of some small quantities of alfalfa seed, the range-stock and wool are the only agricultural products exported from the state. There is a home market for more of the other products of the farm than are raised at present. The feeding industry is beginning to be developed and some finished lambs and beef are going to eastern markets.

The total land area of Wyoming is 62,448,000 acres. Of this, according to the Twelfth Census Report (1900), 8,124,536 acres are in farms, 792,332 acres of which, or 9.8 per cent, are improved land. There were then 6,095 farms in the state. The total value of the farm property was $67,477,407. The total value of the farm products was $11,907,415. The values of the leading products were: Domestic animals, $39,080,158; hay and forage, $2,332,028; dairy products, $421,613; cereals, $528,481.

The land grant college of Wyoming and the federal Experiment Station are parts of the State University, located at Laramie. Connected with the College of Agriculture are several state departments, such as the Department of Pure Food Inspection, in charge of the State Chemist, who is also chemist in the university; the State Board of Horticulture, with the botanist and zoölogist of the university as ex-officio member and secretary; and the state farmers' institutes and short courses, in charge of the head of the agricultural department. The University, Agricultural College and Experiment Station, with the Department of Pure Foods and farmers' institutes, are governed by a Board of Trustees, consisting of nine members, with the Governor and State Superintendent of Public Instruction as ex-officio members. The State Horticultural Society consists of one member from each water division of the state, appointed by the Governor. The state fair is located permanently at Douglas, and is in charge of a Board of State Fair Commissioners, consisting of five members. Other state societies which have to do with agriculture are: Board of Live-Stock Commissioners, consisting of four members; State Board of Sheep Commissioners, of four members; and State Board of Water Control, of six members, with the State Engineer as an ex-officio member. There is an unofficial State Wool-Growers' Association.

COLORADO. (By *W. Paddock.*) Colorado is preeminently a state of special crops and of special agricultural industries, which have been and are now being developed in particular localities, as, for example, potato-growing in the Greeley district, alfalfa-growing and lamb-feeding in the Fort Collins district, cantaloupe-growing at Rocky Ford, and fruit-raising at various points on the western slope. There is less general farming than in most states to the east. The largest farming district lies north of Denver, where alfalfa, all grains with the exception of corn, and sugar-beets grow to perfection. Seven of the beet-sugar factories are located here. The eastern plains are largely devoted to grazing, but dry-farming is practiced to some extent. The Arkansas valley produces a variety of crops, among which may be mentioned fruit, cantaloupes, vegetables, alfalfa, grain and sugar-beets. The principal

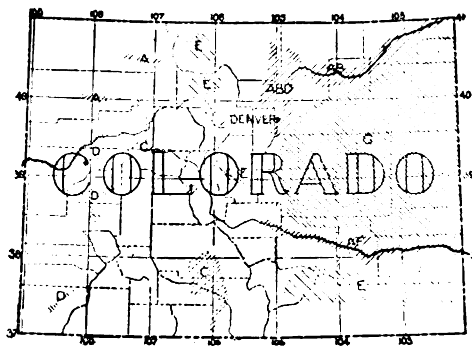


Fig. 88. Agriculture in Colorado.—A, alfalfa, grain, stock-feeding; B, beets; C, potatoes, grain, stock-feeding; D, fruit, potatoes, grain, alfalfa; E, grazing, native hay; F, fruit, cantaloupes; G, grazing, dry farming.

fruit districts are on the western slope of the mountains, in the counties of Garfield, Mesa, Delta and Montrose. Some important potato districts are also included in this section. The San Luis valley, in the southern part of the state, produces grain, potatoes and stock; while in a number of localities in the southwest stock-raising is an important industry, and in some of them fruit-raising is being developed. Vast areas in the mountains must always be devoted to grazing, while numerous parks and the valleys in the northwest supply forage for winter feeding. Stock-raising and feeding is practiced to a certain extent in most of the regions mentioned.

With the exception of dry farming on the plains, all agriculture may be said to be dependent on altitude and an adequate supply of water for irrigation. There is great activity at present in irrigation projects. The feasibility of dry farming over any extended area has not yet been established, though the subject is attracting much attention.

Freight rates must always be high in a mountainous country, because of the expense of building and maintaining railroads, and in the majority of locations there will never be competing lines; hence high charges will probably be the rule, as in the past.

History shows that irrigated regions contain the smallest farms and the highest type of agriculture. Colorado will be no exception to the rule. In fact, the breaking up of the large ranches into small tracts has already begun. It has been demonstrated that five acres of good irrigated land will support a family bountifully. Then the growing of special crops will be largely developed. At present the beet-sugar industry is coming to the front. There were 85,032 acres devoted to this crop in 1905, for which the farmers received $4,647,235. Twelve sugar factories were in operation and four more are contemplated for next season's campaign.

The total land area of Colorado is 66,332,800 acres. Of this, according to the Twelfth Census Report (1900), 9,474,588 acres are in farms, 2,273,968 acres of which, or 24 per cent, are improved land. There were then 24,700 farms in the state. The total value of the farm property was $161,045,101. The total value of the farm products was $33,048,576. The values of the leading products were: Domestic animals, $49,359,781; hay and forage, $8,159,279; dairy products $3,778,901, and cereals, $4,700,271.

The State Agricultural College of Colorado is located at Fort Collins. The federal Experiment Station is a department of it. Formerly, there were a number of branch experiment stations, but all except the one at Rocky Ford have been discontinued. The Board of Agriculture, composed of eight appointive and two ex-officio members, are trustees of the Agricultural College. There is also a State Board of Horticulture, consisting of six members, who are also appointed by the Governor. The duties of this Board are not well defined. The state fair is located permanently at Pueblo. It is in charge of a State Fair Commission consisting of twelve members. The agricultural societies of the state are as follows: The State Horse- and Cattle-Growers' Association, State Horticultural Society, State Forestry Association, State Bee-Keepers' Association.

12. CENTRAL AND SOUTHERN ARID STATES

NEW MEXICO. (By *J. D. Tinsley.*) The agricultural conditions of New Mexico are determined mainly by the topography, which controls the moisture and temperature. The territory consists of a plateau diversified by plains, mountain ranges and valleys. The altitude varies from about 3,500 feet in the southeastern section to about 13,000 feet for the highest mountain peaks. It increases from the south toward the north, and this, with the 400 miles distance from south to north, causes considerable differences in the climatic conditions of the various localities, and admits of the growing of a corresponding variety of crops. The climate is dry in the main, making irrigation a necessity in most places. The temperature also varies very much with altitude and is influenced by latitude and exposure. The low minimum is a controlling factor in crop production, and its effects are manifested in late spring frosts, which occur frequently, say three years in five, doing much damage to fruit and materially shortening the growing season. The rainfall throughout New Mexico occurs mainly in

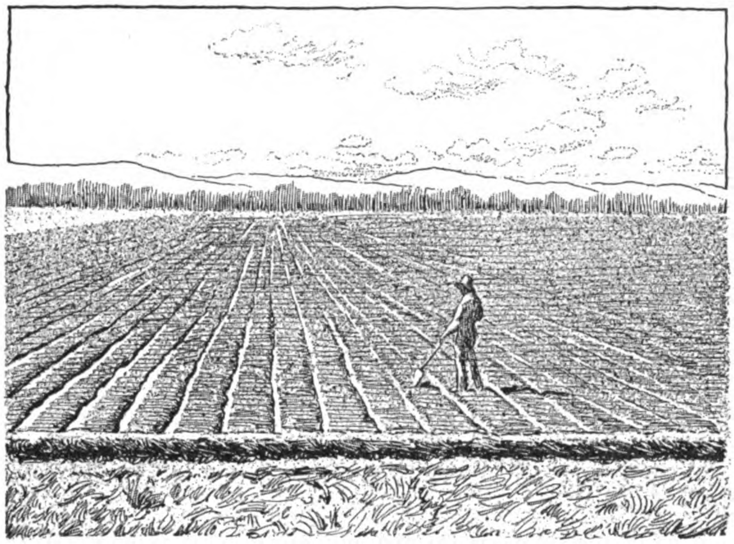


Fig. 90. Ditch irrigation in the arid West.

July and August. The mean annual rainfall varies from eight to twenty-four inches.

The soils of the territory are principally alluvial, very varied in texture, but, on the whole, they are fertile.

The plains and mountains are mainly devoted to raising sheep, cattle, horses and goats on the open ranges; the valleys are devoted to farm crops.

The agricultural districts may be divided into the plains and high mesas where the rainfall, sixteen to twenty inches, is sufficient for farming without irrigation; mountain localities above 5,000 feet, where there is sufficient rainfall or where the rain is supplemented by irrigation from the small streams; and the river valleys, the most important of which are the Rio Grande, Pecos, San Juan, Mimbres, Gila and Canadian. The river valleys are, and will always be, the most important agricultural districts.

Alfalfa is the crop most widely grown and in largest amounts. The yield is much smaller under dry-farming than under irrigation. Indian corn, of the Mexican variety, probably comes next in distribution, and the quantity grown is large. Kafir corn and other giant grasses are widely grown, the largest quantities being produced in the lower Pecos valley and under dry-farming. Wheat, oats, rye, barley and potatoes are grown, and Mexican beans are extensively raised. Cotton is being successfully grown in the Pecos valley and would do well in other parts of the territory. Practically all other crops of temperate climates are grown to some extent. Fruits and vegetables are grown extensively and the acreage devoted to them is increasing rapidly.

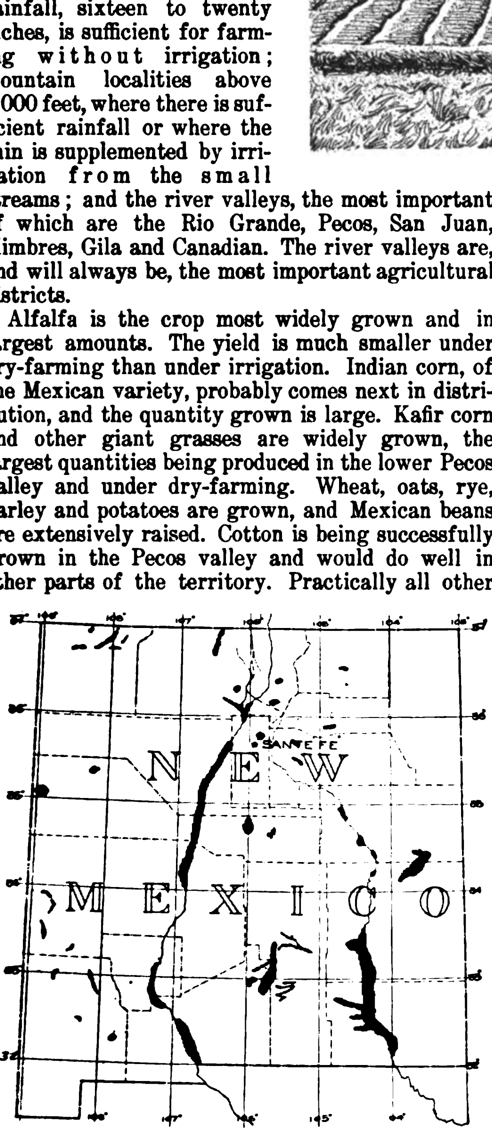


Fig. 89. The shaded areas show the principal regions in which agriculture has been developed in New Mexico.

A large part of the products is used locally in supplying the demands of the towns, ranches and mines; and the prices are comparatively high, because the farmers can hold their products to the price at which such supplies can be brought in, thus getting the benefit of the high freight rates.

The most of the live-stock is raised on the open ranges and shipped to feeders; but in some localities high-grade animals are being raised, and feeding for market, especially of lambs, is practiced.

The construction of several storage reservoirs by the United States Reclamation Service will increase the area of irrigable lands and add largely to the output of agricultural products.

The total land area of New Mexico is 78,374,400 acres. Of this, according to the Twelfth Census (1900), 5,130,878 acres are in farms, 326,873 acres of which, or 6.4 per cent, are improved land. There were then 12,311 farms in the territory. The total value of the farm property was $53,767,-824. The total value of the farm products was $10,155,215. The values of the leading products were: Domestic animals, $31,644,179; hay and forage, $1,427,317; dairy products, $499,423; cereals, $979,903. There are now (1906) 57,000,000 acres of grazing land, 16,000,000 acres of woodland, 4,000,000 acres of forest, 200,000 acres under irrigation, and water that may be made available for 4,000,000 acres.

The agricultural college of New Mexico is located near Las Cruces, under the name of The New Mexico College of Agriculture and Mechanic Arts. The federal Experiment Station is a department of it. There are no other stations or sub-stations in the territory. There is no territorial department of agriculture, nor is the farmers' institute work permanently organized. The oldest fair association is at Albuquerque, which has held annual fairs for a number of years. These are called territorial fairs, but are not under the official control of the territory. There are no territorial agricultural or horticultural societies, but there are several local horticultural societies and farmers' clubs, the most important of which are the horticultural societies of Santa Fe and Roswell. There are several local cattlemen's associations, but the chief object of these is protective.

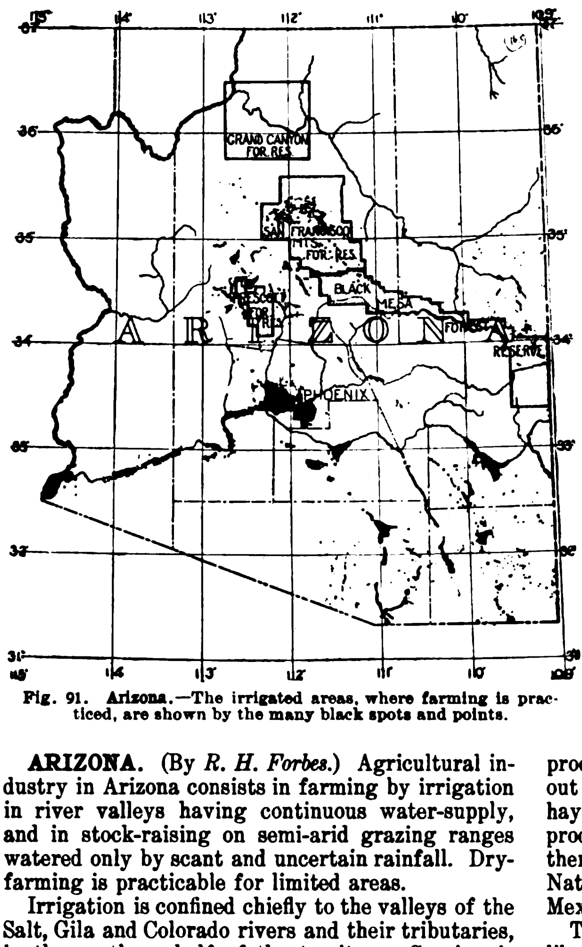


Fig. 91. Arizona.—The irrigated areas, where farming is practiced, are shown by the many black spots and points.

ARIZONA. (By *R. H. Forbes.*) Agricultural industry in Arizona consists in farming by irrigation in river valleys having continuous water-supply, and in stock-raising on semi-arid grazing ranges watered only by scant and uncertain rainfall. Dry-farming is practicable for limited areas.

Irrigation is confined chiefly to the valleys of the Salt, Gila and Colorado rivers and their tributaries, in the southern half of the territory. Grazing is conducted mainly in the eastern and northern parts of Arizona, where forages, both native and introduced, are favored by more abundant rainfall. Dry-farming, i. e., cultivation of the soil with rainfall only, is practiced in occasional northerly or elevated localities.

The agriculture of the semi-arid, subtropical region within which Arizona is included is chiefly determined by a combination of extreme climatic conditions. The most distinctive part of this region, including southern Arizona, parts of southern and central California, and adjacent areas in Mexico, combines less than twenty inches, annually, of rainfall, more than seventy per cent of possible sunshine, sharp frosts (down to 10°F. in winter, long periods of hot weather (average maximum of ninety degrees in July) in summer, and very low atmospheric humidity. This combination of conditions, modified in severity, applies to the United States generally west of central Texas and south of the latitude of San Francisco. Locally, prevailing climatic conditions are modified by elevation, arrangement of land masses, and distance and direction from the sea.

Soils vary physically through all possible combinations of mechanical fineness. Scant rainfall, with consequent small leaching of soluble constituents, has resulted in a general condition of saltiness known as "alkalinity," which is least in well-drained and greatest in poorly drained districts. For the same reason, the soils of the region contain high percentages of carbonate of lime, which, in some localities, accumulates in the form of a refractory hardpan. Consistently, potash is present in high average amount. In nitrogen and humus, however, Arizona soils are deficient, intense summer temperatures causing the decomposition and loss of these ingredients. This is compensated to some extent in irrigated soils by river sediments, rich in organic matter and nitrogen from grazing ranges.

In view of these conditions, rational agriculture in the region involves management of alkalinity in such manner as to prevent harmful accumulations in the soil, and the contribution of deficient nitrogen and humus to the soil. Soluble salts may be disposed of by drainage, or they may be taken up by alkali-resistant plants, such as sorghum. Nitrogen and humus may be supplied by means of leguminous green-manuring crops, such as sour clover and alfalfa.

Railways pass through all of the larger irrigated districts, facilitating shipment of produce to large mining camps scattered throughout the territory. In these towns the demand for hay, grains, vegetables, fruits, poultry and dairy products usually exceeds the supply. Prices are therefore good, although transportation is costly. Native Mexican labor is generally available, the Mexicans being skilful irrigators and farmers.

The development of agriculture in Arizona is likely to be in the direction of smaller farms with very intensive and highly diversified culture, conducted in large part under the improved irrigating water supplies provided by the Reclamation Service. Two Reclamation Service projects, the Tonto and Laguna dams, affecting about 350,000 acres of land, are now under construction, and other excellent sites, covering much larger aggregates of land, are available. Irrigation by pumping is beginning to be practiced and is destined to extend throughout regions of considerable area. With the introduction, also, of drought-resistant varieties of plants and better cultural methods, the area of dry-farming lands, especially in the northern part of Arizona, will greatly increase.

The total land area of Arizona is 72,268,800 acres. Of this, according to the Twelfth Census Report (1900), 1,935,327 acres are in farms, 254,521 acres of which, or 13.2 per cent, are improved land. There were then 5,809 farms in the territory. The total value of the farm property was $29,993,847. The total value of the farm products was $6,997,097. The values of the leading products were: Domestic animals, $15,375,286; hay and forage, $1,362,112; dairy products, $540,700; cereals, $673,639.

Agricultural instruction in Arizona is given at the University of Arizona, is located at Tucson. The Experiment Station, which is a department of it, has offices with the University at Tucson, the station farm being located in an agricultural region near Phoenix. There are three coöperative undertakings with the United States Department of Agriculture, as follows: A date orchard near Tempe, a date orchard near Yuma, and a grazing range reserve near Tucson. There is no territorial department of agriculture. There is an annual fair permanently located at Phoenix. There is an Arizona Agricultural Association, City Park Commissioners and other agricultural organizations.

UTAH. (By *J. A. Widtsoe.*) There are four types of farming in Utah. The first is general farming on irrigated lands and includes the raising of grain, alfalfa and live-stock on farms of forty to one hundred and sixty acres. The important dairy industry comes under this head. The second type is specialized farming on the irrigated lands, and includes orcharding, beet- and tomato-growing and market-gardening. The farms under this type are usually small. The third type is stock-raising on the public range. Owing to the contraction of the ranges, and to the overstocking of them, home winter-feeding of range sheep and cattle is gradually being introduced. This affords an outlet for much of the hay and grain grown by the farmers under the first type. The fourth type is extensive grain-growing on the non-irrigated or arid lands of the state. The farms of this kind cover three hundred to several thousand acres each.

The northern half of the state produces nearly all of the sugar-beets, tomatoes and other crops for the canning factories, most of the fruit and a large part of the dairy products of the state. In the southern part general farming is largely practiced. In the southwestern corner of the state is a depression with a semi-tropical climate and rich soils. The production of grain without irrigation, commonly practiced near the irrigated farms, is rapidly spreading over all parts of the deserts. Stock-ranging is practiced in the mountainous parts and on the western deserts.

The western half of Utah, lying in the Great Basin, consists of a series of parallel north and south valleys, surrounded by large mountains. The eastern half is chiefly elevated table-land, through which run deep cañons. The soils over the whole state are uniformly fertile. In places are found alkali barrens. The climate varies considerably, but is severe only in the mountain valleys. The sunshine is abundant. The rainfall averages about twelve inches yearly. In the north-central part it reaches fifteen to eighteen inches; but over a large part of the eastern and western sections, especially in the south, it is less than eight inches.

The supply of irrigation water comes mostly from small rivers that rise in the mountains and flow into the valleys. The irrigated farms are grouped near these streams. With ten inches or more of rainfall, grain crops can be produced without irrigation; with less precipitation, irrigation is indispensable. The distribution of the farms was originally determined by the availability of irrigation water. The arid or non-irrigated farms are in the regions of the greatest rainfall.

Large mining districts furnish good markets. However, inland states, of comparatively small population, must seek their markets at great distances. Some of the best farming districts are yet at considerable distances from railroads. This deters many fertile and well-watered districts from making the proper development in the raising of fruits and other profitable crops.

Utah agriculture will develop along two lines. The expensive irrigated lands will be devoted

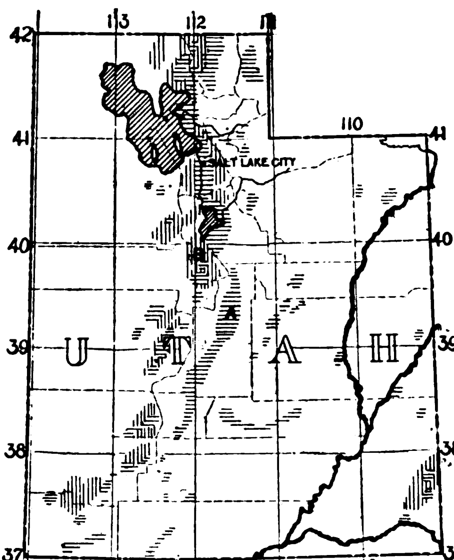


Fig. 92. Agriculture in Utah.—A (horizontal shading), irrigated areas; B (vertical shading), farming without irrigation. The remainder is desert, stock ranges and mountains.

wholly to the production of the most profitable crops, such as fruit, sugar-beets, crops for canning factories and market truck. The grain and alfalfa will be raised on vast unirrigated deserts.

Utah agriculture is characterized by an exceptionally intelligent class of farmers. Agricultural education is fostered by the public and private schools of the state, and all modern advances in agriculture are being tried on Utah farms.

The total land area of Utah is 52,601,600 acres. Of this, according to the Twelfth Census Report (1900), 4,116,951 acres are in farms, 1,032,117 acres of which, or 25.1 per cent, are improved land.

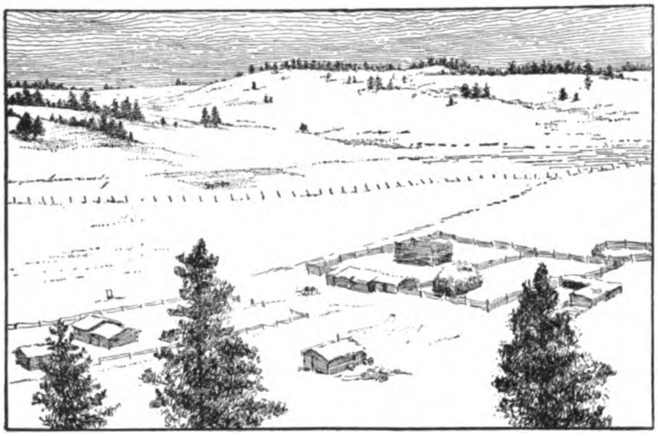


Fig. 93. Utah sheep ranch in winter.

There were then 19,387 farms in the state. The total value of the farm property was $75,175,141. The total value of the farm products was $16,502,-051. The values of the leading products were: Domestic animals, $21,175,867; hay and forage, $3,862,820; dairy products, $1,522,932; cereals, $2,386,789.

The Agricultural College of Utah is the land grant institution of the state. It is located at Logan. The federal Experiment Station is a department of it. Two sub-stations are maintained by the state, located at St. George, Washington county, and Lehi, Utah county. Fifteen hundred dollars are appropriated annually for the holding of farmers' institutes, under the direction of the Agricultural College. The state maintains the Deseret Agricultural and Manufacturing Society, headquarters in Salt Lake City, under the auspices of which state fairs are held. The governing board is appointed by the Governor. The state also supports the State Board of Horticulture, which has charge of all horticultural inspectional duties; the Sheep Commission, which is in charge of matters pertaining to the sheep industry; and a Pure Food Commissioner, who supervises the importation of food materials into the state. There exists, also, a State Dairymen's Association, a State Horticultural Society, a State Bee-Keepers' Association, and a State Poultry Association.

NEVADA. (By *G. H. True.*) The state of Nevada is characterized by a very meager agricultural development. The light rainfall over almost the entire state makes the cultivation of farm crops practically impossible, except in those river valleys where water from flowing streams is available for irrigation. This climatic condition may be given as the reason why the range-sheep and cattle industry is, and probably always will be, the predominant agricultural interest of the state. Next in prominence to the range-stock industry is what may be called grass-and-hay-farming. Probably over ninety per cent of the irrigated lands of Nevada are used for the production of native grass or alfalfa. Comparatively small areas of grain—barley, wheat and oats —are grown, and still smaller areas of potatoes.

In the southeastern part of the state, in the valley of the Muddy river in Lincoln county, is a region where the raisin-grape, figs, pomegranates, the tenderer deciduous fruits and early vegetables are successfully grown. The area that can be cultivated in this valley is limited by the flow of the stream, which is 3,000 inches of water.

In the northern part of the state, which contains all the streams of any considerable size, the liability to frost any month in the year would seem to limit the development of agriculture, except in especially favored localities, to the lines already mentioned. Late spring frosts limit the fruit-growing possibilities.

Horses, cattle and sheep are the only products of the state that are in excess of the local demand. The coast market does not demand high-class products in any of these lines, and excessive railroad rates put the eastern market practically out of the question, so there is little inducement to improve the output. The present farming population is not living up to its opportunities. As a rule, ranches are too large for the best cultivation.

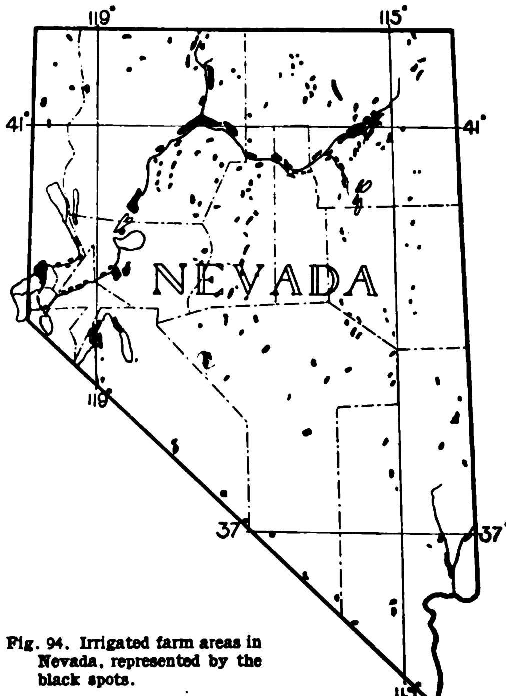


Fig. 94. Irrigated farm areas in Nevada, represented by the black spots.

Advance is to be looked for along the lines of animal production. Dairying, which promises well, is wholly undeveloped, and will surely find an important place in the agriculture of the state. With this will come an increased pork production. So-called general farming is little practiced. There should be development along this line. At present, the live-stock kept on the cultivated ranches is not in proportion to the feed produced, the latter being generally sold for the feeding of other people's stock. The state is particularly adapted to the production of fine stock of all classes.

The cultivated area will always be a very small part, probably not over two per cent, of the total area of the state; but with the proper storage of water and a reasonably economical use of it, the irrigated area of Nevada may be at least doubled.

The total land area of Nevada is 70,233,600 acres. Of this, according to the Twelfth Census Report (1900), 2,565,647 acres are in farms, 572,946 acres of which, or 22.3 per cent, are improved land. There were then 2,184 farms in the state. The total value of the farm property was $28,673,835. The total value of the farm products was $6,758,337. The values of the leading products were: Domestic animals, $12,093,608; hay and forage, $2,067,296; dairy products, $433,391; cereals, $471,090.

The land grant college of Nevada is a part of the State University at Reno, and the federal Agricultural Experiment Station is a department of it. The Lincoln County Experiment Station, located in and intended to benefit the semi-tropical part of the state, was established by an act of the state legislature in 1905. There is a State Board of Agriculture consisting of twelve men appointed by the Governor. It is in charge of the state fair, supposed to be held annually at Reno, and is authorized to collect and disseminate information calculated to benefit the industrial classes and develop the resources of the state. The establishment of county or district agricultural associations is authorized, and county commissioners may appropriate sums not exceeding $1,500 for the support of fairs held by such organizations. The Elko County Cattle Association is an organization of the range cattlemen of that county for their mutual benefit.

13. PACIFIC COAST TERRITORY

CALIFORNIA. (By *E. J. Wickson.*) Three classes of products lead in California agriculture, and each class reaches an annual valuation of about fifty million dollars, viz.: (1) fruit and fruit products; (2) cereal grains and hay; (3) dairy and meat products. Other agricultural products combine to make fifty millions more. The agriculture of the state yields nearly five times the value of its mineral products.

The physical conformation of the agricultural regions of the state consists of great valleys with tributary small valleys and foothill slopes. The mountain ranges prevent entrance of low temperatures from vast interior plateaus of the north and east, and modify the movement of ocean temperatures from the west. The result is that, except in the high mountain valleys, and, to a certain extent, in the northwestern coast region, similar climatic conditions, except as to rainfall, prevail in places of approximately equal altitude throughout the state, and soil areas of similar adaptability are distributed quite as widely. For these reasons, there is no marked isolation of products according to definite physical conditions, although relative importance of the products in different districts does vary according to the tastes or abilities of the people. The temperature extremes are not widely separated. There is not, even up to 4,000 feet on the mountains, such a thing as winter-killing of deciduous fruit trees, nor of growing grain, and hard-frozen ground is seldom seen anywhere. The limiting extremes of low temperature are generally between twenty-five and thirty-two degrees Fahrenheit.

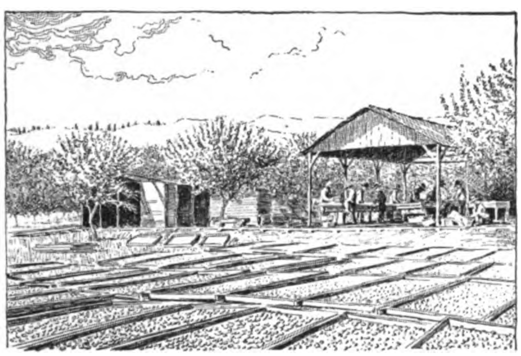


Fig. 95. Drying apricots in California. The sulfuring- and bleaching-house is shown at the left.

Almost infinite variety is characteristic of California as a whole and in its different parts as well. This fact, coupled with the practical absence of wintry conditions, gives the state command of all products grown elsewhere in the United States and many others which cannot be successfully produced elsewhere. The future of the agriculture of the state depends on increase in population to increase home markets, and on the quantity of the distinctively California products which other parts of the world will buy. At present, quick water transportation to Europe seems to be a great determining factor in the development, because the fruit products, honey and the like, as well as grains, are finding a good market there. The Panama Canal is awaited as a beneficent agency. It is to be expected that California will proceed to increase her output of a great variety of products because so many are profitable, and will become more conspicuous, as time goes on, as an epitome of the agriculture of the whole United States in temperate and semi-tropical products. California has no suitability for strictly tropical vegetation.

The total land area of California is 99,950,080 acres. Of this, according to the Twelfth Census Report (1900), 28,828,951 acres are in farms, 11,958,837 acres of which, or 41.5 per cent, are improved land. There were then 72,542 farms in the state. The total value of the farm property was $796,527,955. The total value of the farm products was $131,-690,606. The values of the leading products were: Domestic animals, $65,000,738; hay and forage, $19,436,-398; fruits, $28,280,-104; cereals, $33,674,-733.

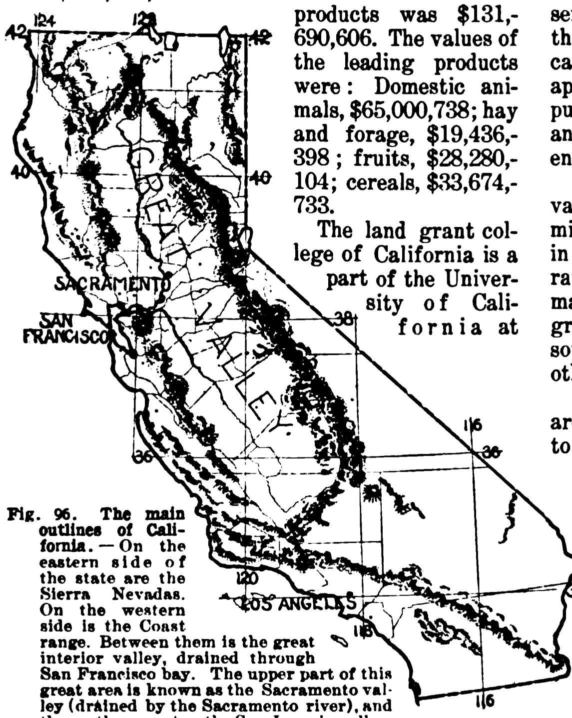


Fig. 96. The main outlines of California.—On the eastern side of the state are the Sierra Nevadas. On the western side is the Coast range. Between them is the great interior valley, drained through San Francisco bay. The upper part of this great area is known as the Sacramento valley (drained by the Sacramento river), and the southern part as the San Joaquin valley (drained by the river of the same name). In the northern part of the state the ranges unite to form the Siskyou mountains, with Mt. Shasta as the highest peak. In the south they unite by a cross range known as the Tehachapi, and beyond this is southern California, with the San Bernardino range separating the highly developed valleys from the arid regions eastward.

The land grant college of California is a part of the University of California at Berkeley, and the federal Experiment Station is a department of it. There are several branch stations of more or less permanence connected with the central station. In coöperation with it also are the United States Seed and Plant Introduction Garden, at Chico, and the Experimental Date Plantation at Mecca. Farmers' institute work is connected with the College of Agriculture at Berkeley. There is a State Board of Agriculture, whose chief duty is the holding of a state fair each year at Sacramento, and the gathering of agricultural statistics. There are executive departments of the state government, in addition, as follows: Department of Highways, Bureau of Labor Statistics, Fish Commissioners, Dairy Bureau, State Veterinarian and Commissioner of Horticulture. Each of these departments has charge of inspectional and police work in its own field. State societies with voluntary membership have been superseded by these official organizations.

OREGON. (By *James Withycombe.*) The state is divided into two grand physical divisions by the Cascade range of mountains, known as eastern and western Oregon. There is also a smaller third division known as southern Oregon. West of the Cascades the climate is humid, while east of this range it is arid or semi-arid. Range husbandry and grain-farming are the principal agricultural pursuits east of the Cascade range. In this section of the state there are approximately four million sheep grazed on the public domain. There are also large herds of cattle and horses maintained, generally within fenced enclosures.

In the plateau section of the Columbia river valley, wheat-raising is the main industry. Twelve million bushels of wheat are now annually produced in this basin, which formerly was the mecca of the rangeman. While mixed-farming is practiced in many instances in this section, exclusive wheat-growing predominates. The common practice is to sow one-half of the farm to wheat and allow the other half to remain fallow.

Within the great "Inland Empire" of Oregon there are large areas of irrigable land which are devoted to the growing of alfalfa, sugar-beets and fruit. Then there are large tracts of sub-irrigated land in this section, the most notable of which is the famous Grande Ronde valley, in the northwest, comprising approximately two hundred and seventy-five thousand acres of fertile soil, on which a wide range of crops flourish.

On the western border of eastern Oregon is located the famous Hood River valley, noted for its superb apples and strawberries. The apples grown here are of superior quality and often top the market in New York and London, their principal outlets.

Western Oregon is noted for its extensive forests and great wealth of rich alluvial soils. The climate is humid and all classes of vegetation common to the temperate zone are found. The principal agricultural lands are alluvial valleys, of which the Willamette is the most noted, embracing nearly 5,000,000 acres of excellent land. This section is the home of the long-wool sheep. It is a great cattle-growing and dairying section, and here the draft-horse develops his highest form. It is becoming famous for its Angora

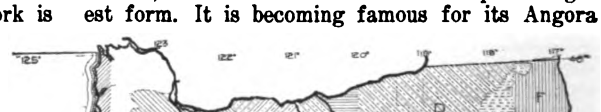


Fig. 97. Agricultural districts of Oregon.—A, dairying; B, dairying and general farming; C, fruit, general farming and stock-raising; D, wheat; E, general farming; F, alfalfa and animal husbandry; G, sheep and cattle.

goats, which number at present nearly two hundred thousand head. Hop-growing is an important industry, yielding annually about one hundred thousand bales. Much fruit is grown, including large quantities of apples, prunes and small-fruits. Nut-culture is attracting attention, though the number of bearing trees is yet limited. On the ocean side of the coast range, in the rich valleys and tide-flats, is a superb dairying section, having green grass the year round. Fruits do well, especially the cranberry. Asparagus, celery and other vegetables of superior quality are produced.

The smallest subdivision of the state is southern Oregon. This comprises the valley of the Umpqua and the famous Rogue river valley, noted for its high-class apples, pears, peaches and grapes. General farming is also extensively practiced.

Portland is the commercial center of the state. Much of the wheat is here ground into flour and the flour shipped to the Orient. The surplus stock is shipped to Chicago or to the corn states. The wool that is not utilized by home mills is sent east, as is also the large quantity of mohair produced.

The total land area of Oregon is 60,518,400 acres. Of this, according to the Twelfth Census Report (1900), 10,071,328 acres are in farms, 3,328,308 acres of which, or 33 per cent, are improved land. There were then 35,837 farms in the state. The total value of the farm property was $172,761,287. The total value of the farm products was $38,090,969. The values of the leading products were: Domestic animals, $33,172,342; hay and forage, $6,147,018; dairy products, $3,550,953; cereals, $9,271,500.

The land grant college of Oregon is located at Corvallis. It is known as the Oregon State Agricultural College. The federal Experiment Station is a department of it. The state maintains an experiment station at Union, in Union county. The state fair grounds are located at the capital city, Salem, and are under the immediate supervision of the State Board of Agriculture, composed of five members, appointed by the Governor. The state also partially supports three district fairs, one in eastern Oregon, one in southeastern and one in southwestern Oregon. There is a State Board of Horticulture, for which the state makes an annual appropriation; there are also the State Dairymen's Association, Oregon Poultry Association, State Horticultural Society and Oregon Good Roads Association.

WASHINGTON. (By *W. S. Thornber.*) There are four types of agriculture in the state of Washington. The first type includes the small grain ranches of the state and might be called general farming. The second type is ordinarily termed grazing, which includes the raising of large numbers of horses, cattle and sheep in the semi-arid regions. The third type is fruit-growing. The fourth is hop-raising.

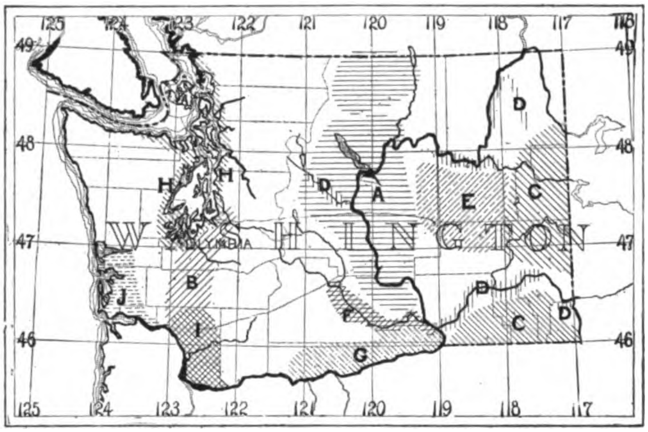


Fig. 98. Distribution of agriculture in Washington.—A, grazing regions (some timber but usually bunch grass); B, hops and small-fruits; C, wheat and fruit; D, irrigated fruit farms; E, wheat; F, fruit, hops and alfalfa; G, wheat, fruit and stock-raising; H, small-fruits, especially blackberries, raspberries, cranberries; I, fruit, especially prunes; J, hops and fruit.

The great wheat ranches of the state are chiefly in the southeast-central, the eastern and the southeastern sections of the state. The grazing lands or bunch-grass hills are mainly in the central and northern parts. Large quantities of fruit are grown without irrigation in the eastern part of the state. There are many large irrigated fruit farms along the Snake, Columbia and Yakima rivers, in the central and southern parts of the state; and fruit-growing without irrigation is very successfully practiced beyond the Cascade mountains. The great hop fields are in the south-central and western parts of the state.

The state is naturally divided into three divisions by the Olympic and Cascade ranges of mountains. First, the division lying between the Pacific ocean and the Olympic mountains is generally hilly and rugged. Second, the part between the Olympic and Cascade mountain ranges includes the Puget sound area and that section in the southwestern part of the state, which is hilly to rugged and usually well timbered. Third, that area east of the Cascade mountains called "The Inland Empire," includes "The Okanogan Highlands," "Columbia River Plains" and "The Blue Mountain District."

The soils of eastern Washington are of volcanic origin, with the addition of local glacial deposits. In some regions rain has encouraged the growth of grass, sage-brush or timber, and the soil is now rich and loamy, while in others the volcanic ash has been only slightly modified and yet stands out as great heaps of ash suitable for agricultural purposes only after being artificially irrigated. Western Washington has an entirely different soil formation. It is practically covered with glacial deposits consisting of gravels, sands and shot clay. Decaying vegetable matter and silt have washed down from the mountain sides until now one finds a deep, rich loam in many places and a dense growth almost everywhere.

The distribution of rainfall of the state is another important factor in determining the types of agriculture. In the small grain belts this does not exceed twelve inches. The annual rainfall west of the Cascade mountains varies from twelve to one hundred and twenty inches. In central Washington it varies from five to sixteen inches; in eastern, sixteen to thirty-six inches.

The transportation facilities of the state are excellent. Three transcontinental roads cross the state from east to west, each terminating on Puget sound. These, in conjunction with other roads, steamboat lines on the rivers and sound, furnish the farmer excellent outlets and markets for his produce, not only to the eastern states but also to the Orient.

At the present time large quantities of small grain are raised, but at the rate orchards are being planted, irrigation ditches being dug for the opening up of new fruit areas, and the improved methods for the transportation of fresh fruits coming into use, we may well look forward to the development of a great fruit-growing state.

The total land area of Washington is 42,803,200 acres. Of this, according to the Twelfth Census Report (1900), 8,499,297 acres are in farms, 3,465,960 acres of which, or 40.8 per cent, are improved land. There were then 33,202 farms in the state. The total value of the farm property was $144,040,547. The total value of the farm products was $34,827,495. The values of the leading products were: Domestic animals, $21,437,528; hay and forage, $5,831,088; dairy products, $3,816,691; cereals, $12,191,397.

The land grant college of Washington is known as the State College and is located at Pullman. The federal Experiment Station is a part of it. There is no state department of agriculture. The work ordinarily performed by such a department is partially done by the Bureau of Statistics, Agriculture and Immigration. There is a Commissioner of Horticulture, appointed by the Governor, who is assisted

Fig. 99. Northwestern hop ranch.

by county horticultural inspectors and deputies, and has charge of all legal, inspectional and general police work as it affects nursery work and fruit-growing. The state fair is permanently located at North Yakima and is controlled by the State Fair Board, consisting of three members appointed by the Governor. The interstate fair is a separate organization, incorporated and controlled by a board of fifteen members. It is permanently located at

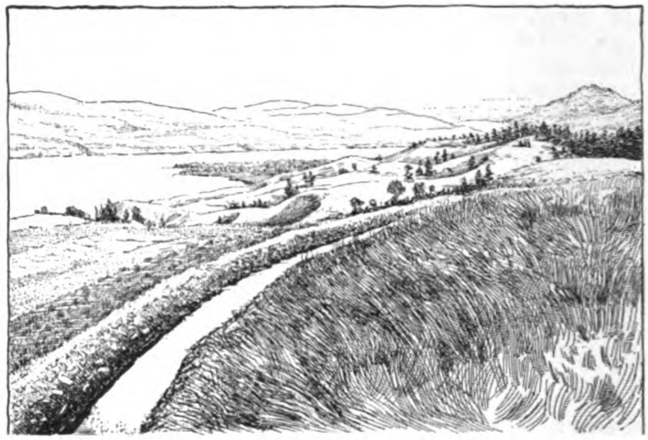


Fig. 100. Irrigation in the interior country of British Columbia.

Spokane. The leading agricultural societies or associations in the state are as follows: State Dairymen's Association, State Live-Stock Association, Inland Registered Stock-Breeders' Association, Washington State Horticultural Association, Washington State Poultry Association, Bee-Keepers' Association, Grain-Producers', Shippers' and Millers' Association of Washington, Hop-Growers' Association and the Northwest Fruit-Growers' Association.

BRITISH COLUMBIA. (By *J. R. Anderson.*) The great province of British Columbia, extending, as it does, north and south, from the forty-ninth to the sixtieth degree of latitude, and from the Pacific ocean to the summit of the Rocky mountains, embraces many and varied conditions. Owing to the diverse climatic and physical changes, which consequently follow, the country presents agricultural problems probably unparalleled in any other country of its extent.

General farming and fruit-culture are practiced in the valleys of the coast and the islands, where the precipitation is sufficient for the production of all ordinary crops. The great interior between the Coast range and the Rocky mountains, owing to the small rainfall, requires irrigation. In the valleys grain is produced and fruit of a most excellent quality; the highest parts are devoted to the production of beef-cattle. Alfalfa and clover give three crops during the year, while hay on the delta lands runs as high as three and even four tons to the acre; oats produces as high in some cases as ninety bushels, and occasionally even one hundred and fifty bushels to the acre. Twenty acres of Northern Spy apples in 1905, in one case, brought over $10,000; one and a half acres of peaches, $700; tomatoes, $1,500 per acre.

For the most part, the coast section is very heavily wooded; the interior section is generally open in the valleys and wooded in the higher parts. The rainfall ranges all the way from two and one-half inches in the most arid parts of the interior to over one hundred inches on the northwestern sea-coast; the snowfall is small throughout the coast region and heavy in the mountainous parts. The temperature in the southern regions seldom goes above seventy-five or below eighteen degrees, and in the interior ranges between one hundred degrees and, in the coldest parts, twenty degrees below zero. Semi-hardy fruits are produced in the hot, dry valleys of the interior, and plants bloom fairly well all the year round on Vancouver island and the mainland adjacent, where the temperature is so equable that change from light to heavy clothing is rendered practically unnecessary in the winter. The markets of the provinces of Alberta, Saskatchewan and Manitoba, and the mines, afford a ready outlet for all the products which those localities are naturally not adapted for producing; the Orient and Australia also constitute good and growing markets. Railroad facilities are good, and great developments are going on, which in the near future will give increased facilities for the cheap transportation of products. The water transportation within the boundaries of the province, owing to the numerous water-ways, rivers, lakes and extensive coast-line, is naturally of the best, and the numerous steamers plying to the Orient and Australia afford every facility to be desired. The population is principally white, from the Old Country, the eastern provinces and the United States; the Indians, about 25,000 in number, are increasing slightly; the remainder of the population is composed principally of Chinese and Japanese.

The area of British Columbia is approximately 245,120,000 acres. The total value of the farm products for 1905 was nearly $6,500,000. The four chief sources of income are cattle, dairying, fruit and grain.

The province has no agricultural college or experiment station, but there is an Experimental Farm at Agassiz with a very large collection of fruits. There is a Provincial Department of Agriculture, which has charge of agricultural affairs in general, the superintending of farmers' institutes and providing judges for fairs. Annual shows are held in various parts of the province, the principal ones being at Victoria and New Westminster.

ALASKA. (By *C. C. Georgeson.*) The agricultural possibilities of the vast region of Alaska are so little known to the general public that it is well worth while to present them in some detail, even though, in so doing, the space devoted to the territory is out of proportion to that given to other political divisions. A discussion of the agriculture of that country will be aided, also, by some account of the other natural resources of the region.

Alaska can scarcely be said to have an agricultural industry. Development in this line has only begun. The greater part of the present white population is there as the result of the discovery of gold, and the energies are directed chiefly to mining and trading. Soil culture and animal industry are limited to supplying a small part of the demand for fresh vegetables, horse feed and milk, as high prices for these commodities make their production profitable. This fact not only proves that their production is possible, however, but it also gives promise of larger development when the economic conditions are adjusted to the needs of a permanent population. A discussion on Alaskan agriculture, therefore, must naturally resolve itself into a consideration of the capabilities in that direction. Interest is centered less in the present stage of development than in the promise of future growth. But, to understand the potentialities, it is first necessary to call to mind briefly the controlling factors in nature. These are, geographic position, physical features, and, as a resultant of these, the climate.

A glance at a map shows that Alaska stretches over some 18 degrees of latitude and 42 degrees of longitude. Much of this vast space is taken up, however, by the long arms of southeastern and southwestern Alaska, which reach out in the directions indicated by their names. The main body of the territory lies between latitudes 60° and 70° north, and between longitudes 141° and 166° west. This position is comparable to that of the Scandinavian peninsula, and in physical features, climate and products, the two regions have much in common.

The area of Alaska is variously estimated, but in round numbers it is 590,000 square miles. Of this area it is estimated that about one-sixth, or approximately one hundred thousand square miles (the area of Michigan and Ohio), can be utilized for agriculture and grazing.

The present population is estimated at 65,000,

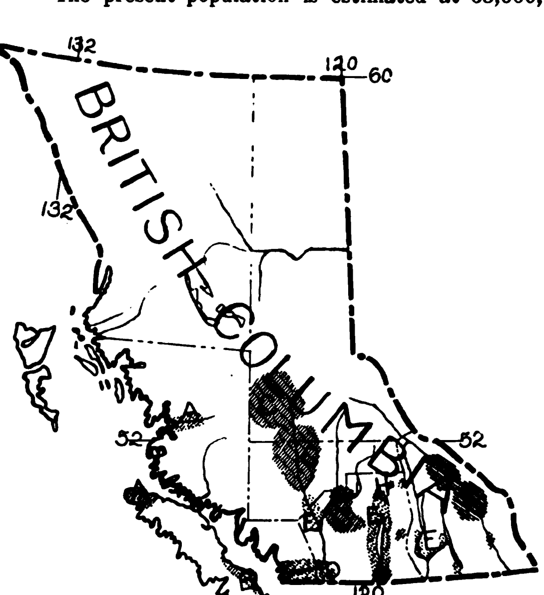


Fig. 101. Map to show the leading areas in which agriculture has been developed in British Columbia.—A, general farming area; B, fruit, general farming, dairying, and at southern end of island sheep, also; C, cattle; D, dairying and general farming; E, fruit; F, fruit and general farming; H, dairying.

one-half of which is native races and the other half whites.

A striking and unique characteristic is the length of coast-line, which is enormously enlarged by the great number of islands that skirt the mainland. This coast-line aggregates 26,000 miles, and is sev-

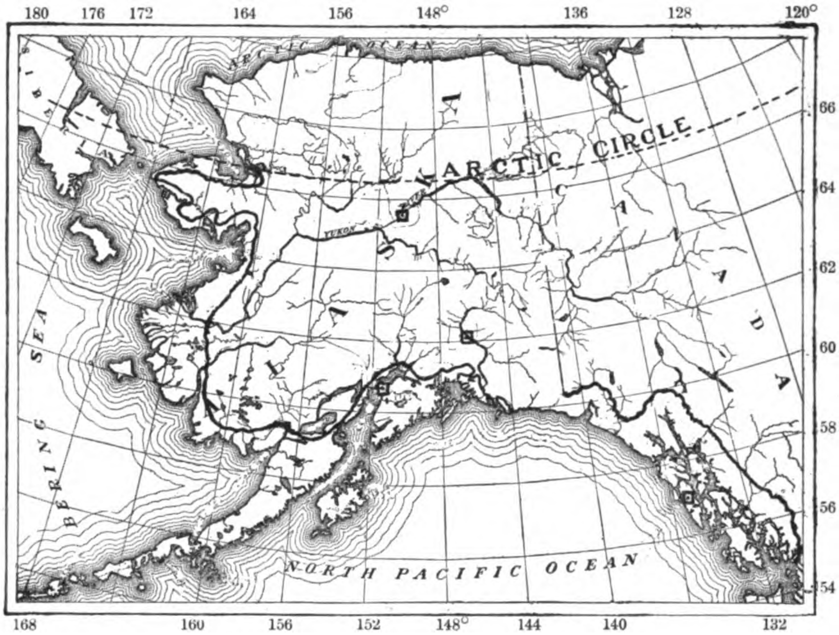


Fig. 102. Alaska.—The heavy line near the coast marks the approximate boundary between the coast region and the great interior region. The four squares represent the United States experiment stations: the one farthest south is at Sitka; the farther west on the gulf (Cook inlet) is the Kenai station; the succeeding inland station is at Copper Center, on Copper river; that near the arctic circle is the Rampart station. Southeastern Alaska is the narrow strip of mainland, with contiguous islands, in which Sitka is located. Southwestern Alaska is the long peninsula, with its contiguous islands.

eral thousand miles more than the coast-line of all the rest of the United States. Another characteristic that has an important bearing on the climate is the fact that the mainland is bordered by a range of mountains averaging between 5,000 and 6,000 feet in height. The highest peak in this range, Mount St. Elias, has an altitude of over 17,000 feet. This range is rough and rugged, and all but the lower elevations are covered with perpetual ice and snow. It divides the "Coast Region" from the "Interior," two belts so distinct agriculturally that they require to be treated separately. The islands that border the mainland are but outlying spurs of the coast range, partly submerged. They consist of jumbled masses of rugged mountains, which differ from those on the mainland only in height.

The leading features of the interior are groups and chains of high mountains, extensive river systems and large river-basins. The mountain chains run, for the most part, in an east and west direction. The highest watershed is the Alaska range, in which Mt. McKinley towers to a height of 20,000 feet, and has the distinction of being the highest peak on the North American continent. It lies in latitude 63° 30′, longitude 151° 15′, about 300 miles from the ocean and about 100 miles south of Tanana river. There are four large rivers in the territory and numerous small ones. The Yukon is the largest. It is navigable for 2,000 miles, and carries a body of water almost equal to that of the Mississippi. The Tanana and Koyukuk, two of its tributaries, are, in themselves, majestic streams. The Kuskokwim lies south of the Yukon, and flows southwest into Bering sea. The Sushitna and the Copper both flow south, the former falling into Cook inlet and the latter into the ocean east of Prince William sound. Each of these rivers has a large valley, or basin, fenced by high mountains. These valleys are not to be thought of, however, as level rich bottom-lands, but as vast stretches of undulating and hilly country, each many thousands of square miles in extent, and each subdivided into numerous smaller valleys, through which flow creeks, rivers and glacial torrents of all sizes and degrees of swiftness.

In far northern latitudes, successful agriculture depends more on the weather than it does in regions farther south. An intimate knowledge of climatic conditions is therefore of first importance. In so vast a territory, with so pronounced physiographic features, there would naturally be great variation in climate. Details cannot be discussed here, but the leading features must be noted.

There are two distinct climatic belts separated from each other by the coast range. They may be designated as the Coast Climate and the Interior Climate.

The narrow belt of mainland and the islands bordering thereon have a climate that is characterized by mild winters, cool summers and heavy rainfalls. The moisture-laden winds from the ocean are chilled in rising over the range, resulting in heavy precipitation. The rainfall is heaviest in southeastern Alaska and gradually diminishes to the westward. At Sitka, on Baranoff island, the rainfall averages ninety-six inches a year. The temperature is uniform and moderate, and seasonal changes come on very slowly. At Sitka the thermometer rarely rises to 80° in summer and rarely falls to zero in winter. In the coast region, as a whole, there is little frost after the first of May, and killing frost rarely occurs before the first of October. The summer has a large proportion of rainy and cloudy days. The rainy weather is detrimental to the ripening of grain and the curing of hay. This fact will always prevent grain-growing in the coast region except to a very limited extent, and the silo must be largely depended on for the preservation of winter feed for cattle.

The interior climate is noted for cold winters, warm summers and light rainfall. The open season lasts only four and a half months, from the beginning of May until near the end of September, and killing frosts are liable to occur at any time after the middle of August. The summer temperature not infrequently reaches 95° Fahr., and in winter it sometimes falls to 70° below zero. Meteorological data have been collected in the interior by the Department of Agriculture during the last few years. At the Copper Valley Experiment Station, the maximum and minimum temperatures between October, 1902, and 1905, were respectively 96°, and minus 60°. The mean daily temperature during June, July and August, for the same years, was 55.13°. The average rainfall for the same period each year, or during the most important growing season, was 3.7 inches, while the average precipitation for the year, including melted snow, was but 9.27 inches. The number of clear days averaged but six to each of the above named months, partly cloudy eleven, and cloudy, fourteen days for each month.

In both the coast belt and the interior there is much variation in the climate from year to year. Some seasons are very favorable to all agricultural operations; others are equally unfavorable. The chief difference between a favorable and an unfavorable season lies in the amount of sunshine. When the period from the beginning of June to the middle of August is bright, all crops flourish, grains mature, and results are most encouraging to the husbandman. When, on the contrary, the major part of that period is rainy and overcast, the temperature remains low, growth is slow, and grains fail to mature. It is to be noted, however, that the long hours of daylight in these high latitudes are very favorable to rapid growth. In bright weather the soil soon warms up, and all forms of vegetation develop with leaps and bounds.

In the moist and comparatively mild climate of southeastern Alaska, vegetation of all forms is very luxuriant. Nearly the entire region is covered with spruce forest, interspersed with hemlock, yellow cedar, and, in moist places, alder. The spruce (*Picea Sitchensis*), in itself a beautiful tree, which furnishes an enduring quality of lumber, is omnipresent. It crowds out everything else, reaching from the seashore to the timber limit, an elevation of 2,500 feet. Trees five feet in diameter are by no means uncommon. It insinuates itself into every cleft and crevice of the rocks, and gives to the landscape a universal somber green, which, contrasted with the snow-capped peaks, produces striking scenic effects. The moist, cool climate fosters certain forms of cryptogams; and the surface of the ground, both in the woods and in the open, to the very snow-line, is covered with a thick coating of moss of many species. The accumulations of ages have formed thick deposits of peat, varying in depth from a foot to twenty or more feet. In the sense of universal distribution, moss may be said to be the dominant form of vegetation. It is found from the spruce forests of the south, westward and northward, to the arctic circle. When tree forms disappear, the moss remains, displacing even the grasses, and covers the tundra in the higher latitudes. The timber is heaviest in southeastern Alaska, and, passing westward, it gradually diminishes in size, until finally, westward of the Kenai peninsula and Kodiak island, the forest disappears altogether, and its place is taken by grass and thickets of alder and willow. Of the minor forms of arboreal vegetation may be mentioned several species of the huckleberry (*Vaccinium ovalifolium, V. parviflorum, V. uliginosum, V. Vitis-Idæa*), the salmonberry (*Rubus spectabilis*), the wild red and black currants, the high-bush cranberry, and others of less importance. Westward from Kodiak, grass is the most important form of vegetation, from an economic standpoint. Along the Alaskan peninsula, the Aleutian islands and the shores of Bering sea, nature has provided a vast amount of pasturage for live-stock, which is but slightly utilized at present.

Passing now to a consideration of the vegetation in the interior, we find spruce still the leading tree, although of another species. It fills the mountain valleys of the Coast range, and it covers the major part of all the valleys already referred to. As one

Fig. 103. Typical Alaska cabins.

goes northward the trees are shorter and smaller, but in latitude 64° trees eighteen inches in diameter are not uncommon, though on the arctic circle the writer has seen few trees more than eight inches in diameter. The birch and balsam poplar in many places dispute the ground with the spruce, the poplar reaching a larger size than the spruce. Along the water-courses are willow thickets. Among the shrubs the huckleberry, raspberry, red currant and high-bush cranberry are the most conspicuous, while the mountain sides are quite generally covered with the scrub birch (*Betula glandulosa*). In places, there are extensive natural meadows, in which the leading grass is the Alaska blue-top (*Calamagrostis Langsdorfii*), which, in favorable localities, reaches a height of six feet; in other places, there are square miles of boggy land covered with sedge; but under and among it all is found the moss, which, as noted, gradually displaces even the grasses near the arctic shores.

The crab-apple (*Pyrus rivularis*) is found in patches and scattered thickets in the coast region. It produces little apples, the size of sour cherries, which make a most excellent jelly. This is the only tree-fruit indigenous to Alaska, unless, indeed, the Juneberry (*Amelanchier Canadensis*) may be classed among the tree-fruits. A few trees of these are found. The other fruits are berries, of the species already mentioned; and, in addition, it should be noted that Alaska has a wild strawberry, which grows for two hundred miles along the exposed sandy beach, from Muir Glacier to Mount St. Elias.

Fig. 104. Clearing land for a garden in the coast region of Alaska.

It has a berry as large as a thimble and of most delicious flavor. Transplanted to garden soil it produces a luxuriant growth, but yields no fruit. The writer has also seen a strawberry in the interior, but it is rare. The berry is no larger than a pea, but is highly flavored.

The agricultural belts correspond to those of the climate, viz., the coast region and the interior. The foregoing data have been given with some detail in order to afford an intelligible basis on which to form an estimate of the capabilities of the country. Experiments by the United States Department of Agriculture, and by settlers, have in a measure defined the limitations of this capacity to produce useful crops, but much remains to be learned.

In the moist coast region all the hardy vegetables thrive with a luxuriance that is scarcely equaled in more favored and warmer regions. Potatoes are, perhaps, the most important crop. They are commonly grown by settlers along the entire coast to Bering sea, and in favorable seasons almost to the arctic circle. Turnips, lettuce and radishes are equally common, and even more successful. The entire cabbage tribe, also peas, carrots, parsnips, beets, parsley and rhubarb, flourish, though beets do not develop roots except under favorable conditions. Onions do not do well from seed, and are therefore commonly grown from sets. Windsor beans and celery can be grown in favorable seasons. Mint, sage, thyme and dill do well, but they are not common crops. All the hardy flowers do remarkably well, and none better than the pansy. Pansies have been gathered outdoors, in Sitka, on Christmas day. The most successful flowers comprise nasturtiums, sweet pea, Shirley poppy, stock, sweet alyssum, mignonette, candytuft, cornflower, wallflower and several varieties of pinks. Roses (excepting *Rosa rugosa*) and flowering shrubs are generally failures.

Market-gardeners, as a rule, are very successful. They are found in every settlement which affords a market for their produce. In growing vegetables, and, in fact, every sort of crop, it is important to choose early-maturing varieties. In favorable seasons, late crops may do well, but they cannot be depended on.

In this coast belt grains are not grown, except to a very limited extent in garden patches, and sometimes on a larger scale for green feed. While there are thousands of gardens, varying in size from a turnip-patch of a square rod to well-managed gardens of fifteen or twenty acres, there is not at this writing a single private farm devoted to grain- and stock-raising, in the sense in which these terms are used in the States. There are several reasons for this. Chief among them is the fact, already noted, that the persistent rain prevents the grain from maturing, except in very favorable years. Second, there is but a limited area of land in the coast region which can be cleared and put under culture at a cost that is not prohibitive to the pioneer. The omnipresence of the spruce has already been noted. Though land is cleared of its timber, the stumps remain and they never rot. They have large root development and, unlike trees in the interior, the roots go deep. To dig or pull them out for anything larger than a garden patch is too expensive at this stage of the country's development. Third, even though grain were grown, there would be no market for it except for stock feed. Fourth, the soil conditions are not favorable in all places, and in some places they are very unfavorable. Drainage is a necessity. The peat formation largely takes the place of humus in the more southern latitudes. Soil of this character is very sour, and, until the acidity is corrected by the application of lime, or by the longer ameliorating process of cultivation, the soil is very generally unproductive. These conditions do not obtain everywhere, but they are frequent enough to demand consideration. That conditions will gradually change, and small farms devoted chiefly to dairying will become established, cannot be doubted. It is an ideal dairy country. The climate is all that can be desired, and green feed and grain for silage can be grown in any quantity. At the Sitka Experiment Station it has been demonstrated that the native grasses make first-class silage. The best species for this purpose is beach-rye (*Elymus mollis*), a tall coarse grass which grows on the beach, just beyond the reach of high water. A sample which had been in the silo a year gave the following analysis: Water, 69.77 per cent. Water-free substance: Fat, 3.32 per cent; protein, 10.64 per cent; ash, 6.89 per cent; crude fiber, 34.64 per cent; nitrogen-free extract, 44.51 per cent. This is rich feed, and with little grain makes an excellent ration for dairy cows.

The western half of the coast region, as already pointed out, has no forest, and, instead, is covered with a luxuriant growth of grass. Here, dairying and stock-raising can be made profitable, with competent management. Cattle can run out nine or ten months of the year, feed is abundant, and for dairying the climate is all that can be desired.

Grain can be grown in the coast region, with the limitations already noted. At Sitka station spring-wheat of excellent quality has been grown two years out of five, and barley and oats have matured every year, though it is often difficult to save these grains. Fiber flax of fine quality has also been grown. The cultivated grasses do exceedingly well, tall meadow oat-grass being the most promising on muck soils. White and alsike clovers are luxuriant and persistent, and red clover usually does well.

Turning now to the interior belt, which extends from the coast range to the arctic circle, we find entirely different climatic conditions. It may be noted, in passing, that beyond the arctic circle, agriculture, in the ordinary acceptation of the word, is not practicable. Turnips, radishes, lettuce and similar quick-growing stuff can be grown, and sometimes potatoes, cauliflower, and even cabbage, but they are doubtful. Barley has been matured at Fort Yukon, just inside the circle, and it is grown as far as latitude 68° in Finland; but at this stage of development it is not necessary to take this into account. The region north of the circle is the legitimate range of the reindeer.

The soil in the interior belt differs much from that on the coast. The dry climate has not been conducive to luxuriant vegetation, and humus is, in consequence, not plentiful. Gravels and sand predominate. One is impressed with the idea that nature has not yet completed her work of disintegration and preparation for the cultivator. The soil is not rich, as a rule, except in creek bottoms and on other deposits of alluvium. Farming lands should be selected with care. The section, nevertheless, has certain advantages over the coast belt. The land is more easily cleared, because the forest is lighter and the roots are on the surface, and a large part of the land is covered only with bushes and grasses. It is a "warm" soil compared with that on the coast,—that is, it responds rapidly to the sun's rays, and growth is forced. There is no difficulty in curing hay or maturing grains, because of excessive moisture. On the other hand, the light rainfall is soon dissipated, and it appears certain that irrigation will be an advantage in many places.

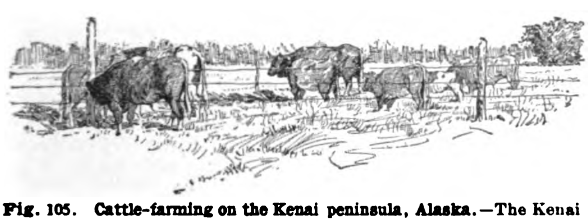


Fig. 105. Cattle-farming on the Kenai peninsula, Alaska.—The Kenai peninsula lies between Cook inlet and Prince William sound.

The United States Government has established two experiment stations in the interior,—one at Copper Center, in the Copper river valley, in latitude 62°, and one at Rampart, in the Yukon valley, in latitude 65° 40′, or less than one degree from the arctic circle. Experiments have been made at the latter station since 1900, and at the former since 1902. Some varieties of grain have been matured at both places every year; and it is a remarkable fact that although the Rampart station is three and one-half degrees farther north than the Copper river valley station, grain-growing has been more successful at this northernmost station. Winter-rye sown in the fall of 1900 matured perfect grain in August of 1901, though the winter temperature was very severe, falling to 70° below zero. The grain was protected, however, with a covering of three feet of snow, and did not suffer. Last winter (1904-05), on the other hand, winter-rye and winter-wheat were partly winter-killed at the same station, because the snowfall was light; although the temperature did not fall below 50° below zero. Early varieties of barley and oats have matured at this station every year, but spring-wheat and spring-rye have not always matured. Seeding should take place as early in May as the ground can be worked after the snow leaves it. Growth is slow at first, but by the middle of July, when the soil has been warmed, it proceeds with astonishing rapidity. The amount of sunshine during the summer has a direct bearing on success. The season of 1905 was abnormally cloudy and rainy everywhere in the interior; growth was slow in consequence, and grain did not mature at Rampart until early September. There had been several light frosts during August, which, however, did not seriously damage the grain. Tender plants, such as potatoes, may be killed at any time during the summer, but grain has not been injured earlier than August 14; and usually frosts hold off until the latter part of the month. Winter grains have never been a success in the Copper river valley, for the reason that the snowfall is usually too light to afford adequate protection. Spring-wheat has matured in the valley only in small protected patches, but early varieties of barley and oats have matured every year when they have been planted early. Early seeding is ab-

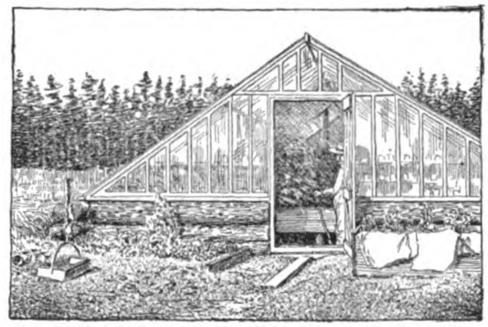


Fig. 106. Market-gardener's greenhouse at Fairbanks, in the central part of Alaska.

solutely necessary, to give the grain a long enough growing period. To this end the ground should be fall-plowed. It can then be seeded, after a working over with a disk harrow, and no precious time be lost in plowing.

Vegetable-growing in the interior is affected by the same conditions. Rapid-growing crops, as radishes, lettuce, turnips, and the like, develop quickly and to perfection; usually also potatoes, peas, the cabbage tribe, carrots, parsnips and beets are successful,—that is to say, they succeed three years out of four, it being understood that early varieties must be planted. Here, again, experiments would indicate that the Yukon valley affords more favorable conditions than the Copper river valley. In the latter place potatoes have never been a pronounced success, while in the former they have seldom been a pronounced failure. In the sisters' garden at the Holy Cross Mission, located on the banks of the Yukon, in latitude 62°, potatoes are a staple crop, and the writer has eaten new potatoes, cauliflower and carrots the first week in August at that place. At Eagle, latitude 64°, potatoes have not only been grown, but have matured so as to keep over winter with excellent success. At Dawson, on the Canadian side, a hundred miles east of Eagle, the writer has seen large and successful market-gardens and collections of fully matured spring grain.

From the results of experiments and the experience of settlers during the past five years, we can safely draw these conclusions: (1) Rapid-growing vegetables can be raised anywhere up to and beyond the arctic circle; (2) spring grains and vegetables requiring a full season's growth for development can usually be grown south of the arctic circle; (3) success depends more on local conditions than on latitude. In some regions grains fail, while in others, farther north by several degrees, they succeed in the same season. It is believed that the valley of the Tanana is particularly well-adapted to agriculture. It runs approximately in an east and west direction, is some twenty-five miles wide on the average and about four hundred miles in length, with high mountains to the north and farther off to the south also. The valley itself is rolling, with here and there rounded hills; and the soil, though light loam, produces large timber for the latitude. The valleys of the Sushitna and Kuskokwim rivers are probably equally good. Each contains many thousands of square miles, and prospectors report that they succeed in raising good gardens. Moravian missionaries on the Kuskokwim and in the neighboring valley of the Nushagak not only have good gardens but have matured grain on a small scale. Cultivated grasses, so far as they have been tried, have done well in the interior. All along the trail where hay has been carried, and around the camps where horses have been fed, timothy and other grasses have sprung up and maintained themselves. It is too cold for red clover, but white clover survives in some places. In the dry Copper river valley *Bromus inermis* is apparently the most promising grass.

There is one condition peculiar to the entire interior which at first sight appears to be an insuperable obstacle to successful agriculture, and that is that the ground nearly everywhere is frozen to an unknown depth. (There are exceptions near warm springs.) Miners find it frozen to bed-rock, even when the rock lies 200 feet deep. At Rampart the writer has found perpetually frozen ground in the shade of the woods and under a six-inch coating of moss, within ten inches of the top of the ground, in July. The roots of the spruce, in fact of all trees, spread out horizontally in the upper layer of this frozen ground. The vegetation preserves the ice, as sawdust does in an ice-house. Where the ground is cleared, it rapidly thaws. In cultivated ground that had been cleared two years, the frost lay two feet deep; and in one place on the Yukon, where the ground had been cleared for many years, a well twenty-five feet deep was dug without reaching frozen ground. The frost is, therefore, no obstacle to plant culture.

Isolated small herds of dairy cows are the only cattle which have so far been wintered in the interior. Herds of beef-cattle, numbering a hundred head or more, are driven from the coast to the large mining camps every summer. These maintain themselves well on the trail, but are butchered in the fall. Stock-raising and dairying must eventually become important branches of Alaskan agriculture, particularly in the coast region. Grains are not always sure to mature, but feed can be grown in any quantity. The grass lands of southwestern Alaska afford an excellent range, and here cattle can run out the greater part of the winter. In the interior, eight months' stall-feeding will be necessary. Galloways and West Highland cattle should be chosen for Alaskan conditions because of their hardiness.

As instances of the abnormal conditions which obtain in the interior settlements, it may be mentioned that hay is worth $160 per ton at most river points, and more, even twice that, when land transportation is necessary. The past summer, 1905, the writer saw a small herd of dairy cattle at Fairbanks whose milk the owner sold for $2.50 per gallon. Twenty-five cents a quart is cheap for fresh milk at any interior point, and ordinary dairy cows are worth from $400 to $500 a head. These conditions, of course, will change rapidly and radically as soon as railroads and wagon-roads are built, so as to make travel and transportation less onerous and costly.

The future success of agriculture in Alaska will depend on the development of varieties of grains and vegetables that are especially suited to the climate. That such varieties can and will be developed, either as a result of crossing or through the gradual adaptation of varieties that already exist, cannot for a moment be doubted. It must be borne in mind that the seed so far used has been grown, for the most part, in regions much farther south. Small quantities of grain from Finland and northern Russia have been tried at the experiment stations, and these have invariably done better than native sorts. In course of time Alaska will develop varieties of its own, and when this is done agriculture will become an established and secure industry. The plant-breeder is very much needed. It is not unreasonable to expect that Alaskan-grown grains and potatoes will find a market for seed in regions farther south.

There are a number of laws bearing on the acquisition of homesteads in Alaska, but the latest and most important is the act of March 3, 1903, which provides that any person competent to exercise homestead rights may file on 320 acres in Alaska. Within six months of making his entry, he must

Fig. 107. Field of barley and oats at the Rampart Agricultural Experiment Station, Alaska, within one degree of the arctic circle.

establish his actual residence in a house on the land and must reside on and cultivate the land continuously, in accordance with law, for a term of at least five years. An occasional visit to the land, once in six months, or oftener, does not constitute legal residence. If these conditions have been complied with, the title can be acquired at the expiration of five years. Settlers are beginning to take advantage of this law, indicating a desire for permanent residence. The writer has knowledge of two hundred homestead entries.

The wealth of Alaska is in its minerals,—gold, copper, coal and oil. No man yet knows how extensive these deposits are. Each year, new discoveries are made. But enough is known to make it certain that the mineral wealth will attract a large population. It will cause the building of railroads and trails and wagon-roads. Several such roads are already building. Rich deposits of placer gold have been found over very extensive areas. It is found in many places on Seward peninsula and on tributaries to the Tanana, the Forty-Mile, the Sushitna and the Kuskokwim, while gold-bearing quartz is abundant in southeastern Alaska and elsewhere. Copper ore in apparently inexhaustible quantities has been found in a belt more than 200 miles long, from the headwaters of the Tanana and the Copper to Prince William sound. Excellent coal has been located on the Matanuska and in Controller bay in enormous quantities, and coal of less excellence is found in a dozen other places. Oil has been located in several places on the coast, and tin mines are being developed on Seward peninsula. The markets which these great interests must produce will, for many years to come, if not for all time, be the chief impulse to the development of agriculture in the larger part of the territory that is adaptable to the production of crops or stock. Gradually farming will become an established industry. The mines of California were at one time the chief incentive to the development of farming and fruit-growing in that state.

The forest belts, and their nature, have already been referred to. It remains to say a word on their economic value. No estimate of their actual value can be made. The forests make life possible in Alaska. Without them the white race would have to live as do the Esquimaux. To import the timber needed for fuel, for mining, for buildings and for structural purposes of all kinds would be well-nigh impossible, with prices prohibitive. At interior settlements, right in the midst of the forests, lumber is worth $100 a thousand board feet, and at the mines, as, for instance, on Cleary Creek, less than twenty miles from the sawmills at Fairbanks, it is worth $225 per thousand. What it would be if it had to be imported can scarcely be imagined. While the forests seem an impediment to progress to the pioneer of the present, their value will be increasingly appreciated as the country is settled and years pass. And it is the forests of the interior that have the greatest value and should receive the most fostering care. Enormous areas of timber are annually destroyed by forest fires in the interior, to say nothing of that consumed for steamer fuel and other legitimate purposes. The next generation will sorely miss this timber. It cannot be replaced. Growth is slow in those latitudes, and a lifetime is but a fraction of the period required to mature a tree. If the indiscriminate destruction is not stopped in the interior, and that soon, and existing forests jealously guarded, development must suffer and permanent settlement be retarded, if not made impossible. The heaviest timber in the territory is in southeastern Alaska; and there the best part has been set aside as a forest reserve, with a view to its protection. This is wise. But there is much greater need of protecting the smaller timber in the interior. On the coast there is practically no danger of forest fires: the rains prevent that; and the forest-clad gorges and mountain sides are, as a rule, so inaccessible that the timber does not readily fall a prey to the woodman's axe. Nature herself protects the forests in the coast region; but in the interior they are open to every sort of destruction, and their loss will be grievously felt by the future inhabitants.

The fisheries should be mentioned because they constitute one of the great resources of the territory. However, they have but a distant bearing on the development of agriculture. The canneries are worked chiefly by Chinese labor. The ships that bring the crews also bring provisions for the season, and when the season closes all connected with the industry leave Alaska. But the value of the fisheries as a source of wealth cannot be measured. Practically every mile of the 26,000 that measure the coast is good fishing ground. Only the salmon streams, and to a slight extent the halibut fishing, have so far attracted the attention of fishermen; yet the annual value of the product amounts to millions.

CHAPTER II

TROPICAL AGRICULTURE

TROPICAL AGRICULTURE is not a system. It is merely a name applied to the miscellaneous agricultural practices that are more or less peculiar to the torrid zone. It is applied to certain cultures. The writings on tropical agriculture are devoted chiefly to a discussion of particular crops, rather than to a body of principles; or, if principles are discussed, they are those that underlie agriculture in temperate regions, only the application of them being modified. It is significant that we do not write of "temperate agriculture": the fundamental agricultural writings happen to have been elaborated in temperate climates; the term tropical agriculture has been applied to later writings that devote themselves to a particular and contrasting field.

What we know as the tropics is not homogeneous territory in any respect. It lies between the Tropics of Cancer and Capricorn; it is the torrid zone: but within this zone are all kinds of geological formations and soils, all ranges of rainfall, all varieties of exposure to sun and wind, and even all kinds of climate, for there are all degrees of elevation. The region is practically only a division on the map. Some of the crops grown between the Tropics are temperate crops occupying elevated districts. Any treatise on tropical agriculture will be found to include crops that grow well in great regions in the United States, as, for example, tobacco, maize, rice, cotton, sweet-potato, sugar-cane. Tropical crops are not necessarily those that require a very high temperature: the most characteristic are those demanding a continuously frostless climate, as coffee and cacao. Those tropical plants that mature in a short season may be grown far beyond the two Tropics, for the summers of the temperate zone may be tropical while they last. Thus, tobacco is always included in tropical agriculture; yet it thrives also in Wisconsin and New England. Some of the tropical plants have been brought to their greatest perfection in extra-tropical regions. If there is tropical agriculture within the temperate zones, there is also temperate agriculture within the torrid zone, as in the cattle-ranging on the high lands. It will be seen, therefore, that it is impossible to limit discussion of agricultural principles or even of agricultural practice by the boundaries of the torrid zone.

When we speak of tropical agriculture, we instinctively think of crops rather than of live-stock. Animal husbandry is relatively small in the tropics. There is a rising interest in stock-raising in the tropics, but this industry can never be expected to occupy the commanding position that it does in cool-temperate zones. Very likely the English system of botanic gardens, which have stood in the place of experiment stations, has had some influence in developing the plant side of tropical agriculture.

Three considerations seem largely to determine some of the main features of cropping practice in the tropics: The long growing season and the absence of winter relieve the necessity of forehandedness in providing for food and shelter, and thereby take away incentive; the climate enervates; the great purchasing populations of the earth are outside the tropics, and therefore tropical agriculture, so far as it is commercial, is essentially an export business. It is now the general tendency for tropical countries to become dependencies of the northern nations. The climatic considerations make for shiftless and easy-going practices; the economic consideration makes for single-crop cultivation in a wholesale way. Mixed husbandry, as it is understood in temperate climates, is practically unknown within the tropics, at least at low altitudes. These considerations, and others, have retarded the study of fundamental questions in the agriculture of the torrid zone. This agriculture is really undeveloped; as such, it offers an almost virgin field for energetic study, organization and development. The tropics have been exploited rather than settled: that part of the earth needs permanent settlement and the kind of development that ensures a careful mixed husbandry.

Temperate agriculture is distinguished by straw grains, sod, forage crops and grazing. Tropical agriculture lacks these elements as distinguishing features (excepting rice among the cereals), and it is very heterogeneous in its characteristics. The leading commercial crop industries in the tropics are coffee, cacao, rubber, banana, coconut, many palm products, manila hemp and other textiles, spices, many dye stuffs and drugs, together with many others that are also adapted to subtropical or even mid-temperate climates, as tea, sugar-cane, cotton, maize, tobacco, rice, citrous fruits, sweet-potatoes, pea-nuts. The literature of tropical agriculture is mostly a discussion of the methods of growing these crops.

The subject of tropical agriculture has now become of prime interest to the inhabitants of the United States in consequence of the development of territorial extension within the torrid zone. We shall now need to follow the English and other European nations in developing what are technically known as colonial industries, having reference to the products and practices of tropical regions. No great schools of agriculture have developed within the tropics, and the field of research is all but untouched. The American's interest in tropical agriculture is chiefly in Porto Rico, Hawaii and the Philippines; accounts of these islands, therefore, for the present purpose may stand for the types of the agriculture of the torrid zone.

Following are leading treatises on tropical agriculture: H. Semler, Die Tropische Agricultur, 4 vols. (2d ed. of vols. 1-3, 1897–1903); M. Fesca, Der Pflanzenbau in den Tropen and Subtropen (1904); H. A. A. Nicholls, Tropical Agriculture (1897); P. L. Simmonds, Tropical Agriculture (3d ed. 1889); Sagot et Raoul, Manuel Pratique des Cultures Tropicales (1893); Henri Jumelle, Les Cultures Coloniales, 2 vols. (1901); J. Mollison, A Text-Book of Indian Agriculture, 3 vols. (1901); Thos. A. C. Firminger, A Manual of Gardening for Bengal and Upper India (various editions); G. Watt, Economic Products of India, 7 vols. (1889–1893; index 1896); C. G. W. Lock, Coffee: Culture and Commerce (1888); E. de Wildemann, Les Plantes Tropicales de Grande Culture; Café, Cacao, Cola, Vanille, Caoutchouc (1903); J. Hart, Cacao (1900); H. Jumelle, Les Plantes à Caoutchouc et à Gutta (1903); W. Bramet, India Rubber, Guttapercha and Balata (1900); H. Lecomte, Le Vanillier (1901); W. Krüger, Das Zuckerrohr und seine Kultur (1899); G. Haarsma, Der Tabaksbau in Deli (Sumatra) (1891); C. Bald, Indian Tea: its Culture and Manufacture (1903). Other writings on the special crops will be mentioned under those crops in Vol. II. Some of the journals devoted to tropical agriculture are: Der Tropenpflanzer (Berlin); Journal d'Agriculture Tropicale (Paris); The Tropical Agriculturist (Colombo, Ceylon); West Indian Bulletin (Barbadoes); Teysmannia (Buitenzorg, Java); Bulletins of the 's Lands Plantetuin (Buitenzorg); Indian Mercuur (Batavia, Java); circulars of the Royal Botanic Gardens (Peradeniya, Ceylon); Indian Agriculturist (Calcutta); Revue des Cultures Coloniales (Paris).

A GENERAL VIEW OF TROPICAL AGRICULTURE

By F. S. EARLE

In tropical countries, most of the crops are different from those grown in the North, but the principles underlying their culture are the same. The practices based on these principles, however, must vary with every change of condition. The most obvious change in condition found on reaching the tropics is the much more uniform temperature. The heat is less intense than that sometimes experienced in temperate regions, and there is no cold sufficient to interrupt the growth of plants.

It must not be supposed, however, that growth in the tropics is continued and unvaried throughout the year. The seasons for the most part are well marked, and are determined by the rainfall and not by temperature. In most tropical countries there are distinct wet and dry seasons, and agricultural practice must be governed accordingly. Even in those regions in which the rainfall is abundant in all the months there is a more or less definite periodicity in the growth of plants, and this must be taken into account by the planter. In the American tropics the rainfall is largely determined by the topography. The prevailing winds are from the northeast. As they come in from the sea, laden with moisture, precipitation is caused when they encounter mountain ranges or high hills. When they pass on to lower lands beyond, they have lost their moisture. Lands to the north and east of mountain ranges, therefore, are wet, while those to the south and west are dry. On the mainland, the eastern slopes of the continental divide have a heavy rainfall, while the western sides are dry, the conditions in many places being those of a desert. On the mountainous islands there is always a wet and a dry side, with strikingly different types of vegetation. On many of the small, low islands the rainfall is scanty.

Topography exercises a strong influence on agriculture. Modern labor-saving implements and machines have nearly all been devised for use in level countries. The opportunities and needs of the great expanses of level fertile lands in the central United States have furnished the incentive for invention in this direction. In rough, broken and mountainous lands, agricultural methods must always be more primitive. Much of the cultivated land of the American tropics lies on or among steep mountains. The varying elevations presented by a rugged topography strongly modify agricultural possibilities. Some tropical crops are adapted to moist, hot, low lands; others will thrive only in the cooler temperatures found at higher altitudes.

The texture and composition of the soil is a factor of the utmost importance in determining agricultural practices. In many places, the rich low lands are stiff and tenacious, becoming very hard when dry and very soft and sticky when wet. They are underlaid by an impermeable clay subsoil, and much ditching is required to drain them sufficiently for most crops. Much of the land devoted to sugar-cane is of this character. Sugar lands are proverbially difficult to cultivate. There are other heavy sugar lands, however, without a clay subsoil, that overlie porous or cavernous rocks which afford perfect natural underdrainage. Here no ditching is required and no ridging up of the rows, since perfectly level culture gives best results. On such soils the object is to retain water, not to get rid of it. Tropical soils vary greatly in fertility. Some, as the sugar lands above described, are very rich and remain productive for many years even under the poorest possible management; others are thin and very quickly exhausted. There are all kinds of gradations between the two extremes. Population is small in the American tropics, and thus far, as a rule, only the best lands have been cultivated. This will not always be the case, as is shown by the tide of immigration and development now setting in this direction. The western movement of population has reached the Pacific ocean, where it is confronted by the legions of Asia, and it must of necessity turn southward. Modern sanitary science is fast robbing these tropical countries of their menace to health, and the fable that a white man cannot work in the tropics has been long since disproved. As the pressure of population increases, methods for utilizing the poorer tropical lands will be devised. Where the climate is so propitious, useful crops of some kind can be secured even from the poorest and thinnest soils.

Tillage, so universal in the North, is poorly understood and scarcely practiced in the tropics. It is true that a crisis has now been reached, and on the low lands it has become absolutely necessary to adopt the better and more economical methods of cultivation, especially with products, such as sugar, that meet fierce competition in the world's markets. On the other hand, the adoption of clean cultivation and constant tillage on the more broken uplands would be disastrous. Under tropical conditions fermentation and nitrification are proceeding continually in the soil, not being interrupted by cold. Vegetable matter of all kinds is quickly decomposed; such accumulations of humus as are common at the North are seldom found. Tillage tends to increase these activities and to make the reserve plant-food in the soil available. Taken in connection with the heavy rainfall of most of these regions, which so quickly washes or leaches out unused soluble matter, excessive tillage will result in quick exhaustion of fertility. In a broken region, too, frequent stirring and loosening of the soil causes it to be washed away much more quickly, and fields so treated would soon be ruined by gullying. Besides its action in promoting nitrification and hastening the solution of the mineral food elements, the chief function of tillage is to conserve moisture. In many tropical regions the rainfall is excessive, for a part of the year at least, and the problem is to dispose of surplus water rather than to conserve it. Moreover, many of the cultivated tropical crops were originally forest plants and thrive best under what are practically forest conditions. It often happens, therefore, that methods which to northern eyes appear exceedingly shiftless and neglectful are in reality the best that could be adopted.

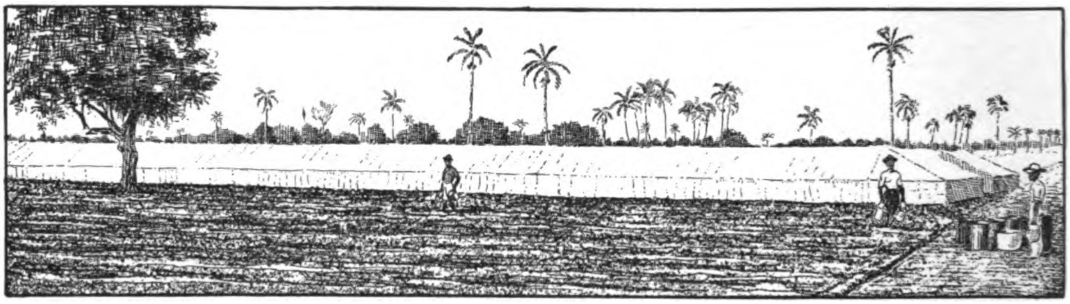


Fig. 108. Cheese-cloth tent for growing high-class wrapper tobacco in the Partidos district, Cuba.

Agricultural methods in the western tropics are, for the most part, still very primitive. The settler clears a space in the forest. The fallen trees are burned where they lie and seeds or young plants of whatsoever kind are planted among the blackened stumps and logs, by means of a sharpened stick or hoe. Vines and bushes are cut down with the machete from time to time, but no other cultivation is given or required in the rich virgin soil. When the planting ceases to be productive, the land is more than likely abandoned, to grow up in vines and bushes; or, if grass springs up, it may be utilized for pasturage, while other tracts of forest are cut down for the growing of crops. In the older and more densely populated regions, these abandoned fields are utilized for a second planting by cleaning the surface with a hoe or with the crude native plow drawn by oxen. This plow is little more than a crooked stick shod with iron, but it still serves its purpose almost to the exclusion of other tools. A mat of bamboos serves as a harrow. What after-tillage is attempted is done with this same wooden plow or with the hoe.

Methods of transportation and marketing are equally primitive. Roads are few or none, produce being mostly carried on the backs of mules or horses and over trails that seem impassible. Little or no attention has been paid to the breeding of improved plants or animals. Live-stock of all kinds is small and poor, owing to lack of care and to long-continued inbreeding. The fruits are all seedlings and the garden vegetables are small and inferior, owing to poor cultivation and lack of care in the selection of seed.

The conditions above described may be taken as representing the present average condition of American tropical agriculture. Signs are not wanting, however, of a rapid change. The better classes of the native populations are highly intelligent, and they begin to feel strongly the need for radical improvements. Keen-minded adventurous foreigners of all nations are flocking to these countries in constantly increasing numbers and are bringing with them improved implements, seeds, live-stock, and a knowledge of the best modern methods. Already with some crops and in a few regions tropical agriculture is taking an advanced position. The Hawaiian sugar-planters, with their skilful use of modern implements, fertilizers and irrigation, hold the world's record for sugar production. The tobacco-growers of western Cuba, aided by the favorable soil and climate, have for years produced the finest tobacco that is known. In Jamaica there are herds of grass-fed Hereford cattle equal to those fattened in the Kansas corn-fields.

The radical changes in method that are necessary before tropical agriculture can take its true place in the world's economy are thus seen to be well-begun, at least in favored localities. What these changes are will be considered more in detail under three headings.

A. The wider use of improved implements and machinery.

Hand labor is slow and expensive. The use of implements cheapens production. These are facts that are not yet fully realized in the tropics. The sugar-planters of Jamaica and Porto Rico still open holes with the hoe for planting sugar-cane instead of using a sulky lister for opening a deep furrow. In Cuba the lister is now in general use, but the cane is covered by the hoe, while a disk cultivator would do the work as well, thus saving the labor of twenty men. The immense cane-fields of the tropics are still mainly cleared of grass and weeds by the hoe. This is ruinously expensive. Cultivators drawn by animals would do the work much more cheaply and much better, since, besides destroying the weeds, they aërate and pulverize the soil. The disadvantage of excessive tillage under tropical conditions has been pointed out in a previous paragraph. In the level cane-fields, however, tillage becomes a necessity if one is to secure maximum crops, except from virgin lands; yet tillage worthy of the name scarcely exists. Cane-planters need to study and to copy the methods of the corn-growers of the Middle West. The two plants are closely related, and their needs are much the same. The rice crop of the tropics is all planted and harvested by hand. Therefore, it cannot compete with that of Louisiana and Texas, which is planted with the drill and harvested with the self-binder. Cheapening production by the adoption of better methods and implements must be counted today as the greatest need of tropical agriculture.

B. Soil-improvement.

Little attention has been given in the tropical countries of this hemisphere to the fundamentally important questions connected with maintaining and increasing the fertility of the soil. Nature's bounty has been drawn on lavishly, while the only restorative measure adopted has been the turning back of impoverished lands to be built up by slow natural processes. This system is wasteful and can be tolerated only when land is cheap and population sparse. Since live-stock is not housed on the farms, stable-manure can be obtained only in the neighborhood of the towns. It can never be relied on here as the basis for soil-improvement. Green-manuring supplemented by commercial fertilizers must largely take its place, yet green-manuring is but little understood, or practiced, while commercial fertilizers are as yet used only for a few crops in restricted localities. The flora of the tropics is rich in species of leguminous plants, some of which are undoubtedly adapted to each of the manifold conditions of soil and climate that are presented. Many of

Fig. 109. Pineapples, widely grown in tropical and subtropical countries.

them seem to be well-suited to purposes of soil-improvement, but their practical usefulness has scarcely been tested. Of the soil-improving plants known and used in the United States, cowpeas, velvet-beans and beggar-weed seem fitted to a wide range of tropical conditions, and are proving exceedingly useful. The trial of the more promising native plants of each of these countries will doubtless show that some of them are even better adapted to local needs. By growing leguminous crops for green-manuring it is possible to maintain in the soil a good supply of vegetable matter and humus, thus securing the mellow, friable texture that is so desirable, and at the same time furnishing a supply of nitrogen. These

Fig. 110. To show that sugar-cane may profit by fertilizing in the tropics. The part on the right has been fertilized with tankag eand potash at rate of 500 kilos. per hectare; part on left unfertilized. Cuba.

are exceedingly important points in the tropics, where fermentation and nitrification go on so rapidly, and where the soil is exposed to the wasteful action of such heavy rains. On the rich, heavy soils, of which there are so many, it is possible by this means alone to keep up the fertility for a great many years. On the lighter soils, however, the phosphoric acid and potash are soon exhausted, and even on the best lands, if they are subjected to continued cropping, a time will come when the available supply of these elements will begin to fail. When such a deficiency occurs, the only recourse is to the use of commercial fertilizers. Such a condition has now been reached on many of the older sugar lands of the West Indies, and the intelligent use of fertilizers will unquestionably be profitable here, as it has already been proved to be in the Hawaiian islands. In the light soils of the Vuelta Abajo of Cuba, the famous tobacco crop is practically all grown by the use of commercial fertilizers. Fig. 110 indicates results that can be secured with sugar-cane.

Many of the low lands of the tropics require drainage. At present, drainage is universally effected by open ditching. These ditches, though comparatively cheap as to first cost, are very expensive to maintain; they waste much land, transport weed seeds, and greatly impede cultivation and the transportation of crops. Ultimately, drainage will doubtless be accomplished by tiling, as is now the case in all regions where the best agricultural practices prevail. A useful beginning in this direction has recently been made by the Porto Rico Experiment Station.

In the hill-lands drainage is seldom needed, but here the problem is to prevent loss from washing and gullying. When crops requiring tillage are to be grown on these lands, great advantage would unquestionably come from adopting the system of terracing so widely used by the cotton-planters in the hill-lands of the southern United States. In planting the more permanent crops, such as coffee, cacao, fruits, and the like, which are usually grown under forest-like conditions, it will be advantageous to locate the rows on contour lines, circling the hill, as it is often called, not only to prevent washing but also to facilitate the gathering of the crop; since, in following such a row, the harvesters will always be walking and carrying their burdens on a level.

Crop rotation and the greater diversification of crops are questions intimately associated with preserving the fertility of the soil. In most tropical countries, the tendency is to depend too much on a few great staples, such as sugar, tobacco or coffee. This is unfortunate from an economic as well as from an agricultural standpoint. The continued growing of the same crop on the same land year after year tends to the early depletion of fertility, while a carefully devised rotation of crops does much to preserve it. Rotation becomes possible only when there is diversification. Again, continuous cropping tends to increase the trouble from insects and diseases. An abundant and continuous food supply necessarily aids in their multiplication, while a proper rotation of crops is often one of the best means of combating pests, since it can be so planned as to cut off the food supply of those which threaten to become troublesome. In any well-considered plan for rotation, some leguminous plant for soil-improvement should be frequently introduced, and this is particularly necessary in the tropics. Here, however, advantage may often be taken of the long growing season by planting a soil-improving crop during that part of the year when the fields are not occupied by the principal money crop, thus providing for what is practically a short rotation without losing the use of the land for the principal crop. This is notably the case with tobacco, which occupies the land for only three or four months. The growing of cowpeas or velvet-beans on tobacco lands during the off season will do much toward decreasing the size of the fertilizer bills.

C. Selection and breeding.

One of the most notable defects that a visitor notices in a tropical market is the poor average quality of the fruits and vegetables. The fruits are always seedlings and consequently lack uniformity in quality, and the vegetables, for the most part, are poor degenerates, showing absolute lack of attention to the principles of plant-breeding and seed selection. With the staple crops it is much the same. Even in the famous Cuban tobacco-fields no attempt has been made at seed selection, and plants of the most varied types are found growing side by side. The seeds for the next planting are saved indiscriminately from the weak suckers that spring up from near the roots after the harvesting of the crop. The mere recording of such facts at once indicates the vast possibilities that await the intelligent plant-breeder in the tropics. Here Nature is in her most bounteous mood, and there is every reason to expect that the hybridizer and breeder will be able to produce a richer array of variations from which to make his selections than is possible under the more rigorous conditions of cold climates. The very fact that all the native fruits are seedlings gives the trained horticulturist a wonderful opportunity for selection, and makes it possible for him quickly to obtain great results by the propagation of the many valuable kinds that already exist, but which are now so completely neglected and overlooked.

With domestic animals the case is much the same. Chickens, pigs, cattle and horses are all, as a rule, small in size and poor in quality. Perhaps an exception should be made in the case of cattle, for in many countries, thanks to rich natural pasturage, these have retained sufficient size; but they are coarse in build and slow in maturing, and entirely lack the fine qualities of the improved breeds. The opinion prevails very widely that there is an inevitable tendency for domestic animals of all kinds to deteriorate when taken to the tropics, and that in a few generations the descendants of even the best-bred animals will be no better than the native stock. Carefully conducted experiments are lacking by which to prove whether or not there is any real foundation for this belief. It is certain, however, that most of the existing deterioration is due not to climatic causes, but to the absolute neglect of all hygienic conditions, lack of proper food and shelter, and to careless inbreeding or promiscuous crossing with inferior strains. Many tropical countries are already great producers of cattle. Experience in Jamaica, and to a less extent in Cuba, demonstrates that it is as possible to produce good cattle as poor cattle. Serious diseases seem to be no more prevalent than in the North. With cheapness of production, made possible by the wonderful pasture grasses and forage plants, it seems probable that the center of meat production, as well as of population, will soon swing markedly southward.

AGRICULTURE IN THE AMERICAN TROPICS IN ITS RELATION TO PLANT INTRODUCTION

By DAVID FAIRCHILD and O. W. BARRETT

Tropical agriculture is radically different from the agriculture of the temperate zone. Farming as it is understood in this country does not exist along the equator, for animal husbandry is almost unknown there. Cattle and hogs, it is true, are raised in small numbers for family use, but dairying and stock-raising for the slaughter-house are industries of small importance when compared with the plantations of the great staple crops grown for export.

There are no great markets for farm produce in the tropics. The aim of tropical agriculture has been to produce something that is wanted by the great cities of the North, and the whole history of the growth and development of certain tropical colonies has been dependent on the demand for a single tropical product in the northern centers of civilization. Cane-sugar was a luxury to supply which the vast cane-fields of the oriental and western tropics were developed; spices were worth their weight in gold in the days of Ferdinand and Isabella, and the Portuguese sailed around Africa in search of the spice islands of the Moluccas. The introduction of the coffee-drinking fashion into Europe is responsible for the beginning of vast coffee plantations that now cover thousands of square miles in Brazil and the islands of the East and West Indies. The mountains of south India, Ceylon, Java, China and Japan are now covered with tea-plants, the infusion of whose leaves was an unknown drink in Europe three lifetimes ago. When Markham, at the risk of his life, got the Cinchona plants from the Peruvians, it was a paying industry that he transplanted, an industry created by the discovery of the antipyretic value of quinine.

As its past history has been closely bound to the wants of the great buying markets of temperate zones, so the future of tropical agriculture lies in the discovery of new uses for the thousands of foodstuffs, fibers, spices, woods, gums, and the like, with which the marvelously varied plant-life of the tropics is replete. And because this plant-life is so varied and the plant products are so localized, much of the history of tropical agriculture is the history of plant introduction, the transfer and spread of plant cultures from one country to another in the same torrid zone. In other words, the great problems of the tropics are problems of plant

Fig. 111. Mangosteen, said to be the most delicious of tropical fruits. Size of an orange.

introduction, the creation of new plant industries. This is not to say that there are no other fields in which, within the next quarter of a century, modern agriculture will make great advances, for it is clear that in matters of plant-breeding, propagation, fertilization and diseases, tropical planters have a right to expect very unusual developments.

Americans are interested not only in tropical American territory, but are pushing their inquisitive way into the great regions of Mexico, Central and South America, and scattering themselves throughout the torrid zone; so that brief forecasts of new crop possibilities may be of interest to them.

Fruit industries.

Fruit-growing in the American tropics, though horticultural in character, is rapidly becoming one of its greatest agricultural industries. The new fruits that have come into popularity within the last fifteen years have been nearly all of tropical or subtropical species, notwithstanding the fact that fruit-culture in the tropics is almost wholly undeveloped. The possibilities in the way of entirely new northern fruits are almost exhausted, while the wealth of delicious fruits of the torrid zone has barely been explored.

There are no other tropical territories so favorably situated as the West Indies and Hawaii for the encouragement of tropical fruit-culture, and it seems incredible that industries which offer so much have been so evidently overlooked by those who should encourage them. The example taught by the growth of banana-culture in Jamaica and Central America should be taken seriously, for some of the most delicious fruits in the world are waiting to be introduced into the western tropics and grown for the American market.

The mangosteen (Fig. 111) should head the list of new fruit possibilities for the western tropics. Known in the Orient as the "queen of tropical fruits," it is, without question, the most deliciously flavored fruit of that marvelously rich fruit region, the Malay Archipelago. When once known, Americans would pay fancy prices for it; and it is so delicate that it never cloys and a man can eat dozens in a day. Yet with all these possibilities, combined with good shipping qualities, the mangosteen still remains practically unknown in the West Indies, two trees in Jamaica and two in the Trinidad Botanic Gardens being the only ones on record. The genus to which this practically uncultivated fruit belongs has over sixty-five species, and counts fifteen edible-fruited forms among the number, one of these being as large as a Rocky Ford melon. Hitherto, the weak root-system of the mangosteen has stood in the way of its general cultivation, but no careful attempts have been made to graft it on other stocks. The trained horticulturist, by breeding and grafting, has in this family of *Guttiferæ* a field for his activities more remarkable and promising than that of the Japanese plums so well worked out by American horticulturists.

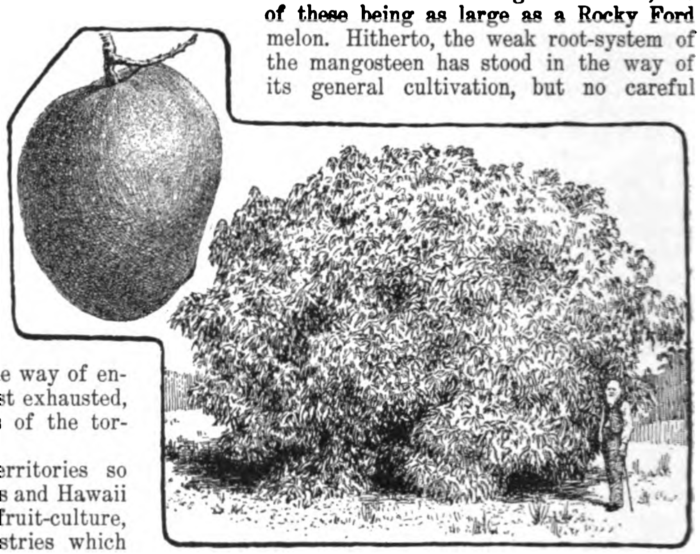


Fig. 112. Mulgoba mango. The first of the East Indian varieties planted in America.

A fruit that will be planted in considerable areas in the tropics sooner than the mangosteen is the East Indian mango (Fig. 112). The East Indian varieties of this fruit are not to be confused with those now growing in the American tropics, and even already to be had on our large markets. The latter are such rank-flavored seedlings, with disagreeable turpentine taste, that it will be difficult to convince those who have tried only the West Indian mangos that those of the East Indies are so different as to deserve rank as a new fruit. The eastern mango is one of the richest flavored, most enticing fruits in the world, and combines, in its custard-like pulp, the fragrance of the apricot and the pineapple. A wonderfully prolific cropper, long-lived, quick in growth and flourishing in poor soils that are not over-wet, the mango has possibilities for the western tropical horticulturist possessing shipping facilities, which deserve his most serious and immediate study. Already in Florida, Hawaii and Porto Rico, the Office of Seed and Plant Introduction of the United States Department of Agriculture is making a special point of establishing the best varieties from India, the Malay Archipelago, the Philippines,

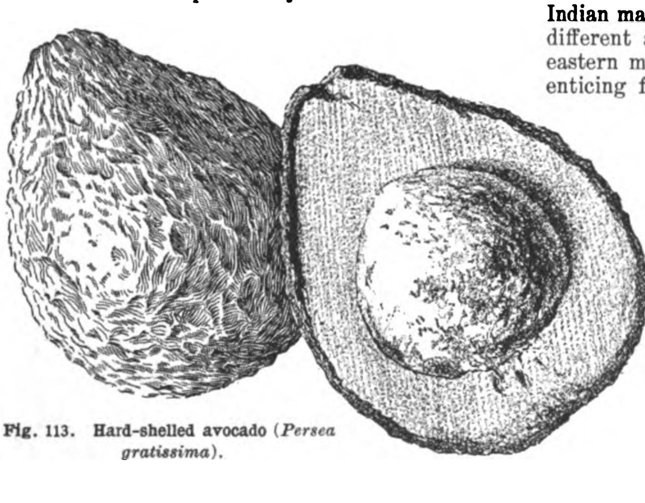


Fig. 113. Hard-shelled avocado (*Persea gratissima*).

the East Coast of Africa and the South Sea Islands, and it will not be long before these delicious mangos are on our great markets, where they are sure to attract attention.

It is a mystery why the Chinese leitchee, or litchi (*Nephelium Litchi*), and its Javanese relatives, the ramboetan and capoelasan, have never found their way into the tropics of the Occident, when one considers that they are among the showiest of all table fruits and are more delicate in flavor than the richest of plums. In southern China these are the most highly prized of all fruits, and there is one variety that is said to be reserved exclusively for the highest officials. In Honolulu, the Afong leitchee tree, growing in the yard of a former Chinese resident of the place, produced in 1904 about two thousand fruits, which sold in the local markets for three cents each. In this group of fruits, of which there are a dozen or more varieties, lies an industry that will one day cover hundreds, perhaps thousands, of acres of tropical hillsides with orchards.

Throughout the wonderfully fertile island of Java, the natives sell, in immense quantities, braided bunches of a delicate fruit called the doekoe (*Lansium domesticum*, family *Meliaceæ*), which, even as a botanic garden plant, seems quite unknown to the American tropics. The possibilities of this plant, the straw-brown fruits of which are keenly relished by the jaded appetites of the Dutch colonists, are still quite unexplored.

Fig. 114. Yautia, showing style of plant and a flower-spatue. A new vegetable possibility.

Recently, in nearly frostless southern California, a new fruit from Argentina and southern Brazil has come into cultivation,—*Feijoa Sellowiana*, of the family *Myrtaceæ*. Plants of this species have already borne a few velvety and exceedingly fragrant guava-like fruits in the gardens of that region, but its prospects and those of its three or more nearly related species or varieties are among the unsolved problems of the tropics.

Fig. 115. The edible roots of the yautia.

One of the latest arrivals in the northern markets is the avocado (*Persea gratissima*). Its increase in public favor as a salad may be judged by the fact that in the Bellevue-Stratford Hotel in Philadelphia nearly two hundred fruits a day are now used, while two years ago not a dozen were served. A variety from Central America, discovered by M. G. N. Collins, and having a tough, shell-like rind (Fig. 113), should show better shipping qualities than those heretofore grown in Florida, Hawaii and Porto Rico. The Florida varieties are already being given special names, as are the mango and orange; and, since these are being propagated by budding, the unreliable seedlings are now used only for stocks. Some twenty varieties are now recognized when a few years ago there were believed to be only two, and among them is a "seedless" sort. Two other related species of the genus Persea are also being tried as stocks. Persea is a genus of the *Lauraceæ*. The fruit of *P. gratissima* is variously known as avocado, avocado pear, alligator pear, aguacate.

Were these few examples not enough to give some hint of the untouched possibilities of fruit introduction in the tropics, the merits of the eugenia, anona, sapodilla, passion fruit, and the amatungula (a Carissa, family *Apocynaceæ*) with very many others, might be presented.

Tropical vegetables.

The yautias, or taniers, and the taros, are among the most promising of the many root-crops of the tropics to the modern agriculturist (Figs. 114, 115). Until recently, both were confused in nearly every account of them, but it is now generally known that all true taniers belong to the genus *Xanthosoma*, while the taros all come under the genus *Colocasia*. These crops have been under cultivation longer, it is believed, than any other, and are probably the only ones that never produce true seeds. For many years, varieties have been grown on a small scale in the southern states, but the recent appreciative interest in taro flour will encourage the extensive cultivation of the sixty or seventy-five varieties of these very interesting aroids. There are few crops that can be grown under a greater variety of conditions of climate and soil than the old yautias of the Arawaks. The numerous varieties fall into about eight distinct types, and new ones are being brought to light in Mexico, Central America and Colombia. In Porto Rico the yield of yautias is two to four times that of potatoes, or from five to ten tons an acre. The taros do not yield so heavily, but can be grown in very wet land. The leaves of both taro and yautia are excellent when used as a spinach, the rich milky juice that fills the entire plant giving a "body" not possessed by most greens. Though ranking on a par with sweet-potatoes as to nutritiousness, the digestive principle contained in taro and tanier renders their roots a perfectly safe diet. A kind of taro, called "dasheen" in Trinidad, can be harvested in about six months after planting; and it is believed that this can be grown successfully at least as far north as the Carolinas.

As soon as the great superiority of cassava starch over wheat starch is more widely known, a steady supply from Porto Rico and Hawaii will be necessary, and much work will be done to introduce hardy varieties from Brazil and Colombia, and in selecting seedlings and in hybridizing. Cassava flour made from the yellow- as well as the orange- and white-rooted varieties should find a ready market.

Yams (species of Dioscorea) cannot compete with potatoes in price, and therefore must be studied from the table luxury point of view. Already one kind, the yampee (*Dioscorea trifida*), has been highly praised in several of the eastern cities, the mealiness, violet color and rich, nutty flavor placing it in the highest class of vegetable foods. The famous East Indian sorts should be introduced into Hawaii and Porto Rico.

The apio (*Arracacia esculenta*) of Venezuela, as indispensable to Venezuelans as is the potato to Americans, has been recently introduced into Porto Rico, where it already compares very favorably in price with the native vegetables; and there are indications that it could be grown in southern Florida. It is one of the *Umbelliferæ*.

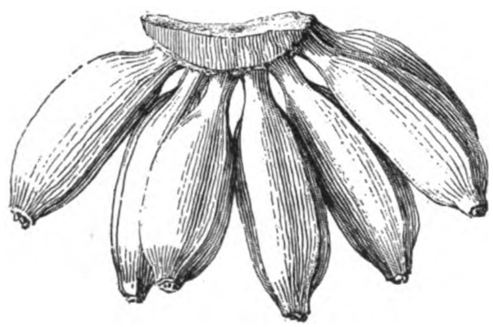


Fig. 116. The date type of dessert banana.

Although commonly classed as fruits, the bananas are quite as properly vegetables. Of the fifty or more varieties of bananas, only three are known to us,—the plantain, now a staple article of food in New Orleans, the common Jamaica, and the semi-ornamental red banana which is occasionally seen in our eastern markets. As soon as a constant and reliable demand is created for plantain flour, banana-coffee and preserves, as well as for the dainty date bananas for desserts (Fig. 116), the planter will no longer grow only the old kind, which ships well and stays longest in the stomach.

The chayote (*Sechium edule*, family *Cucurbitaceæ*), although in common use by the creoles of New Orleans, has, until recently, remained entirely unknown in the North (Fig. 117). To create a demand for this vegetable, plantings were made in Porto Rico and the Carolinas of the superior Mexican varieties, and the fruits were sent to the chefs of the Waldorf-Astoria and Bellevue-Stratford hotels, who reported most favorably on them, and kept them on their menus as long as the shipment lasted. The fruit is about six inches long.

Fig. 117. Chayote (*Sechium edule*).

Tropical nuts.

The American taste for salted and roasted nut-kernels has grown remarkably in recent years, and the almond orchards of southern Spain have grown accordingly. Yet with this development of a great market for roasted nuts, the planters of the tropics have not awakened to the opportunity nor brought forward one of the most delicate nuts of all,—the cashew, *Anacardium occidentale*, a native of the western tropics. Occasionally seen in confectioners' windows, its name is yet unknown to the public, though in delicacy and sweet flavor no nut in the world can surpass a freshly roasted cashew-nut. The London market has in this respect outstripped ours, and on Picadilly the cashew-nut is sold as an expensive delicacy in glass-stoppered bottles. Nor are the posssibilities of the cashew confined to its nuts, for the fruit is delicate, and, either fresh or preserved, is eaten with a keen relish by Americans. Also, a good wine is made from its very juicy pulp. The varieties of this nut-bearing tree have not received even the passing attention of horticulturists, and their number is unknown.

Of all the stately avenue trees of the tropics, none surpasses the Amboina almond (*Canarium Amboinense*, family *Burseraceæ*), and, although pictured in the reports of the botanic gardens of Java, so far as known the tree has never found its way into the western tropics. The nuts of this tree are sold and relished by Dutch and Javanese alike in the Malay Archipelago, and the kernels have even been recently used with remarkable success by a Dutch pharmacologist as an ingredient of infant food. Many of the Dutch babies in Java are said to be brought up on it.

Coconuts are known throughout the tropics, yet little has been written on them and no monograph exists on the varieties of this, the most remarkable money-making nut in the world. In the Orient it is estimated that there are twenty to one hundred varieties, and in a single Ceylon collection, which one of the writers has visited, more than a dozen distinct kinds exist, with varying characteristics of tree as well as of nut. Among them is one sort even the husk of which is edible, and another with fruits not over six feet from the ground. Plant introduction should be at work collecting the best of these for trial in the western tropics, determining which are best suited for desiccation and which for copra, for oil, and for butter.

It is of interest to know that a small plantation of the sugar palm (*Arenga saccharifera*) of the East Indies has been started in Porto Rico. This palm, which may be tapped for about fifteen consecutive years, produces perhaps the most delicious form of sugar in all the vegetable kingdom. Palm nuts, from which each year the millions of buttons of vegetable ivory are made, are imported in amounts valued at more than $5,000,000, yet no culture of any of the four or more species of these plants has ever been undertaken, and the life-history is a matter of conjecture to most botanists. Is the culture practicable, and where can it be conducted on a big scale?

In the markets of Hong Kong are sold each year hundreds of bushels of a hard-shelled, sweet-kerneled acorn, which deserves to be known by the nut-eating public. This tropical oak (*Quercus cornea*, Fig. 118) is probably cultivated above Canton on the North river, and would, without doubt, thrive in the American tropics, and be not only a decorative addition to the shade trees, but add another delicate nut to the list of nut-foods. The Queensland nut, or Fiji nut (*Macadamia ternifolia*) is another of the neglected tropical possibilities which deserves to be studied. It is one of the *Proteaceæ*. Still another is the *Caryocar nuciferum* (*Ternstrœmiaceæ*), or butternut, of the Guianas and Brazil, one of the largest and best-flavored nuts in the world.

In the culture of the well-known peanut, which is one of the profitable crops of the tropics, the problem receiving most attention is that of the introduction of new varieties. At the present time the Mauritius variety is being imported into Ceylon in large quantities for trial; a Javanese peanut has been a great success in Cochin China; and the oil-producing varieties of West Africa are being tested in the peanut-growing regions of this country.

Fibers.

The demand for tropical fiber-plants supports two great monopolies,—the manila hemp industry of the Philippines, and the sisal hemp industry of Yucatan. Neither of these plants—the one a banana, the other a century plant—has been as yet successfully cultivated on a large scale in any other territory than that in which it is at home. Yet the value of the imports of these two fibers into the United States is in the neighborhood of $11,000,000 and $16,000,000, respectively. Two such valuable cultures can scarcely fail to spread into other tropical territories, and already there have been established in Hawaii and Porto Rico small plantings of the sisal hemp which promise to be successful, while plantings of the species of banana which yields the abaca, or manila hemp, are being made in Borneo and Sumatra. The zapupe (*Agave* sp.) of the Tampico district of Mexico, has several qualities that are superior to sisal hemp, and its culture is also likely to spread.

Fig. 118. Acorns or nuts of *Quercus cornea*.

The rattan of commerce comes from species of climbing palms that are now gathered only in the tropical jungles of the Philippines and adjacent regions. The enormous quantities of this fiber used for chair-bottoms, has in recent years advanced the price materially, and the time of its cultivation may not be far off.

The boll-weevil in the American cotton-belt and the consequent advance in the price of cotton, have set tropical agriculturists seriously to work to find new cotton-growing areas as well as new "resistant" varieties, and the recent introduction of the sea-island cotton into the West Indies, the extension into the Soudan of the Egyptian cotton area, the propaganda for a culture in Ceylon, and the increasing interest in cotton-growing in East Africa and Australia, are evidences of how quickly tropical agriculture is affected by changes in the American and European markets.

Beverage-yielding crops.

Three of the greatest beverages known are the product of tropical plants, yet the merits of those other tropical beverages, the South American maté

(*Ilex Paraguensis*) and Arabian kât (*Catha edulis*, family *Celastraceæ*), have never been given the attention by Americans that they deserve. Of the former, there are some twenty million devotees

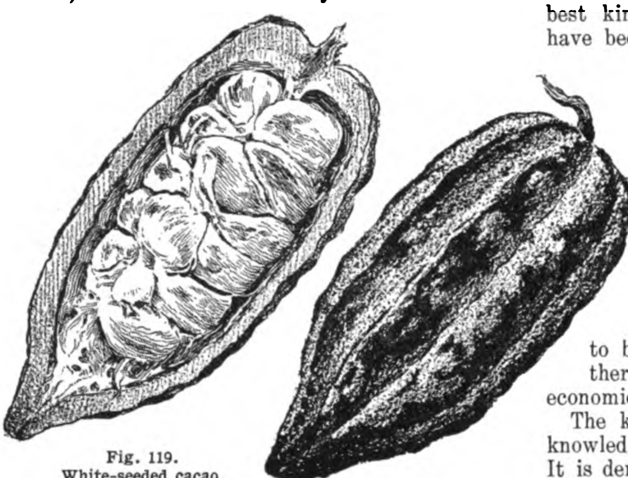


Fig. 119.
White-seeded cacao.

in South America who consume over fifty-five thousand tons a year; and the natives of Arabia prize the latter so highly that special taxes are levied on the dried leaves and the greatest care is exercised to prevent an evasion of the tax by the grower. Of the innumerable fruit-wines and beer-like "chichas," there are very many in the torrid zone which may some day support small industries.

Tea, originally a plant-culture of the temperate, or at most subtropical zone, in comparatively recent times has become one of the great crops of high altitudes in the tropics, and the history of its introduction into Java, Ceylon and Assam, following the destruction of the coffee estates by the coffee leaf-disease, is one of the interesting chapters in plant introduction. So recently has tea been grown in Ceylon that until three years ago the process of green-tea-making had not been introduced, and in consequence the teas from these regions were all of the black type. Fortune's search through the tea-growing sections of China for the best tea varieties for the British is among the best known expeditions in search of plants for a new agricultural industry.

In coffee-culture, which has undergone so many radical changes since its introduction into the vast plain region of southern Brazil, the future outlook is along the lines of plant introduction. The interest in the new *Coffea stenophylla* and *C. robusta*, and the attempt being made by the United States Department of Agriculture to secure for coffee-breeders the original wild coffee of Abyssinia, all show the tendency to recognize the degeneration that has been going on in the cultivated coffee-plant and the need of an invigoration by crosses with the wild type.

The rapid growth of the use all over the world of the cocoa bean and its derivatives, cocoa, chocolate and cocoa butter, has led to the extension in the eastern and western tropics of the areas devoted to its cultivation, and to a more careful study of the numerous widely different varieties which are in existence. Of all the Central American cacaos only two, the famous and probably the best kinds, *Theobroma pentagona* and *T. bicolor*, have been successfully introduced into the great cacao center of the western hemisphere,—Trinidad. Already, Hawaiian planters are calling for the best sorts for their young plantations, and the government is making collections from the West Indies for them as fast as the unusual difficulties of their transportation can be overcome. The white-seeded variety of Porto Rico (Fig. 119), there considered superior to the purple, should be studied; moreover, the quasi-natural hybridization of the six or eight common forms of cacao promises to be a fertile field for the plant-breeder, and there are millions of dollars to be gained by economic methods in the fermentation of the beans.

The kola nut is firmly established in popular knowledge through the beverage called coca-kola. It is derived from uncultivated plants in western Africa, some of which have lately been introduced into the West Indies. According to Cook and Collins, however, the species introduced is not one of the finer varieties from the hinterland, but is the inferior "baboon kola" of the coast region of Liberia.

Grain crops.

The great grain crop of the world is rice,—not wheat or corn, as the American farmer thinks,—for there are more people dependent on rice than on any other food in the world. Notwithstanding all the study that has been given its culture, the best rices of one region are totally unknown to the rice-growers of another, no comparative study of the varieties grown in different countries having been made to find out which are best. Ceylon is following the example set by America and is introducing the Kiushu rice of Japan and the Carolina Gold seed-rice. The American tropics grow mainly upland rices, and these in such small quantities that the tropics depend largely on imports from the Texas and Louisiana rice region for its supply. Porto Rico alone imports over two million dollars' worth of

Fig. 120. Native Mexican method of tapping for rubber.

rice annually, though it contains thousands of acres of irrigable land now idle that should produce more rice than the population of the island consumes.

The tropics lie outside the best corn-growing region, and the finest varieties of maize quickly deteriorate when tried in them; but scattered through the torrid zone are many sorts of corn adapted to tropical conditions, which are worthy of introduction and selection.

Plant extracts.

The number of tropical plant species that yield valuable extracts is too long to be more than mentioned. Two examples will show the chaotic condition of their present culture.

Recent discoveries by Professor P. H. Rolfs have shown that in vanilla-culture alone there is a great future for plant introduction. A wild vanilla, carrying a high percentage of vanillin, has been found by him in the Florida swamps, and a trip made by him to the famous Mexican vanilla region revealed that these plantations are producing less than five per cent of their possible output. This state of affairs should encourage the procuring, testing and breeding of the most promising among the thirty or more species of this genus which are scattered over tropical Africa, America and the East Indies.

Only two rubber-producing plants may be said to be actually under cultivation at the present time. The several forms or species of Castilloa (*Urticaceæ*) of Mexico and Central America are giving good promise of financial success; and the plantations of Para rubber (Hevea) in the Orient have already yielded profitable returns. Those varieties capable of withstanding a dry climate can probably be grown in Hawaii and the West Indies. Attention should be directed to those plants which, like the African *Carpodinus* spp. and *Landolphia Thollonii* (both of the family *Apocynaceæ*), whose roots are rich in rubber, and the newly discovered Colombian and Peruvian species of Sapiums (*Sapindaceæ*), are promising forms for introduction

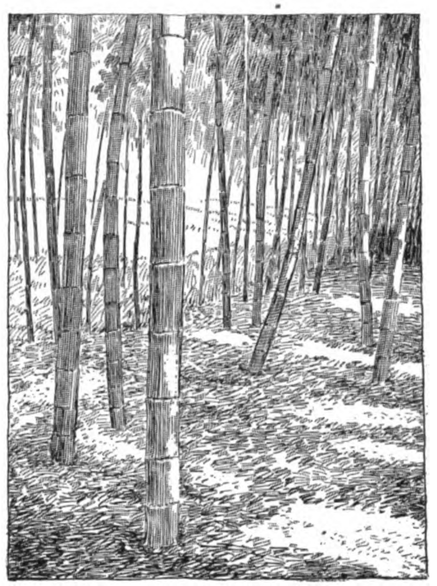


Fig. 121. A bamboo forest in Japan. A suggestion for the American tropics.

into tropical territory. The varieties of Para rubber will some day be studied out and the rubber of commerce, that is growing in importance every year, will be furnished by cultivated areas of known species, instead of, as now, by totally wild and some of them unidentified forest species.

AGRICULTURE IN PORTO RICO

By D. W. MAY

Porto Rico is the easternmost island of the Greater Antilles, and is situated between 65½° and 67¼° west longitude, and between 18° and 18½° north latitude. It is a continuation of the range of mountains of which Cuba, Hayti and San Domingo form a part. It is well within the tropics, some 1,400 miles southeast of New York and a little more than that east of New Orleans. The island is thickly settled with a mixed population.

The physical features.

Porto Rico is a parallelogram, extending east and west, approximately 36 miles wide by 100 miles long, embracing an area of 3,600 square miles. The island may be classed as mountainous, the greater part of it being rough and broken. The island is an uplift, the rocks consisting principally of limestone, together with small amounts of granite, marble, sandstone and serpentine. The limestone varies, in some parts being of a blue or grayish crystalline material, and in others of white and chalky appearance and sponge-like in texture. The latter is generally known as coral limestone. Some of these limestones make excellent road-building materials, and also produce a good quality of lime.

The island is bordered by low land of greater or less extent, forming about one-tenth of the whole area. The main range of mountains extends almost due east and west, but the watershed of the northern part of the island is about two-thirds of the entire width; the rainfall on the northern side is also much greater, and the rivers are much larger on that side of the island. The weathering and washing of the mountains has filled up many of the valleys with alluvial soil. These form plains near the seashore, broken here and there by projecting hills.

The interior is cut by deep and narrow valleys, the bottom-lands being small, irregular areas, occurring first on one side and then on the other of the stream as it sweeps rapidly toward the sea. In some sections of the interior the valleys widen into considerable areas of bottom-land.

The mountains are rough and rugged, but do not extend much over 3,000 feet in elevation. The highest point, El Yunque, is in the northeastern part of the island, which has been set aside by the United States government as a forest reservation. About 75 miles to the north of Porto Rico is one of the deepest parts of the Atlantic ocean,—4,600 fathoms, or more than five miles.

The climate of Porto Rico is very uniform in temperature. The rain in most sections is abundant. A part of the day is sunshiny, the humidity relatively high and winds slow and constant. The mean annual temperature is about 78°, the winter months averaging about 8° Fahr. cooler than the summer months. The changes are so slight that they are seldom noticed, the rainfall making the perceptible difference. The mean temperature is slightly lower in the elevated parts of the island, but the weather may be described as perpetual summer. The annual rainfall varies greatly in

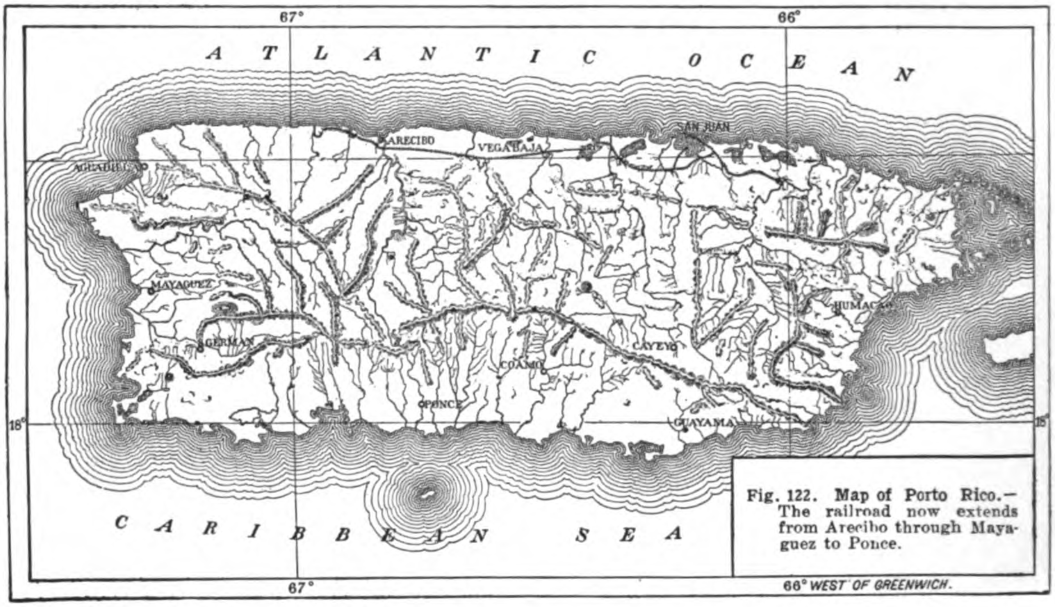


Fig. 122. Map of Porto Rico.—The railroad now extends from Arecibo through Mayaguez to Ponce.

The mountains of the island are not high enough to materially modify the temperature, but they have a marked effect on rainfall. The various climatic conditions have a marked influence on vegetation, which is very different in various sections. The soil varies very much in composition. Near the seacoast it consists largely of a coral sand. The flora of this sand is somewhat limited, consisting of coconut palms, yaray palms and sea grapes. Next are the mangrove swamps, which are inundated by rising tides. This soil is made up of a mixture of coral sand and organic matter, the latter giving to it a black color. It is necessarily alkaline, and its usefulness is very limited, except with a great deal of labor and diking.

The playa plains, extending around the island, are alluvial in their origin and vary in different sections. On the northern side they consist of sandy loam underlaid with clay. When they are properly drained they make excellent cane and pasture lands. On the southern side of the island the soil is deeper and usually more sandy. For the production of cane it requires irrigation during the dry season. Bordering the playa plains, the foot-hills soils are usually dark in color. Farther inland the soil is composed of a moist, heavy red clay.

different parts of the island, ranging from 140 to 150 inches as a maximum, to a minimum of about forty inches. As a rule, the winter months are drier, but the seasons vary in duration in different parts of the island. Very heavy rains are sometimes recorded, amounting to as much as ten or more inches in twenty-four hours. The prevailing wind is from the northeast, and in passing over the mountains it is cooled to such an extent that its heavy charge of moisture is condensed and falls on the northern side of the island; for this reason the rainfall on that slope far exceeds that on the other. As a rule, the mornings are cloudless and the showers fall in the afternoon. These showers are often very heavy, but soon pass away. The streams rise very rapidly, and carry much sediment.

Fogs occur in the mountains, but are not common in the lowlands. The climate is generally healthful. There is usually a breeze, and, although the temperature is that of summer, it is not so oppressive as the hot months in the States. The nights are cool and conducive to sleep.

Economic features.

There is a railroad extending from San Juan around the western end of the island to Ponce on

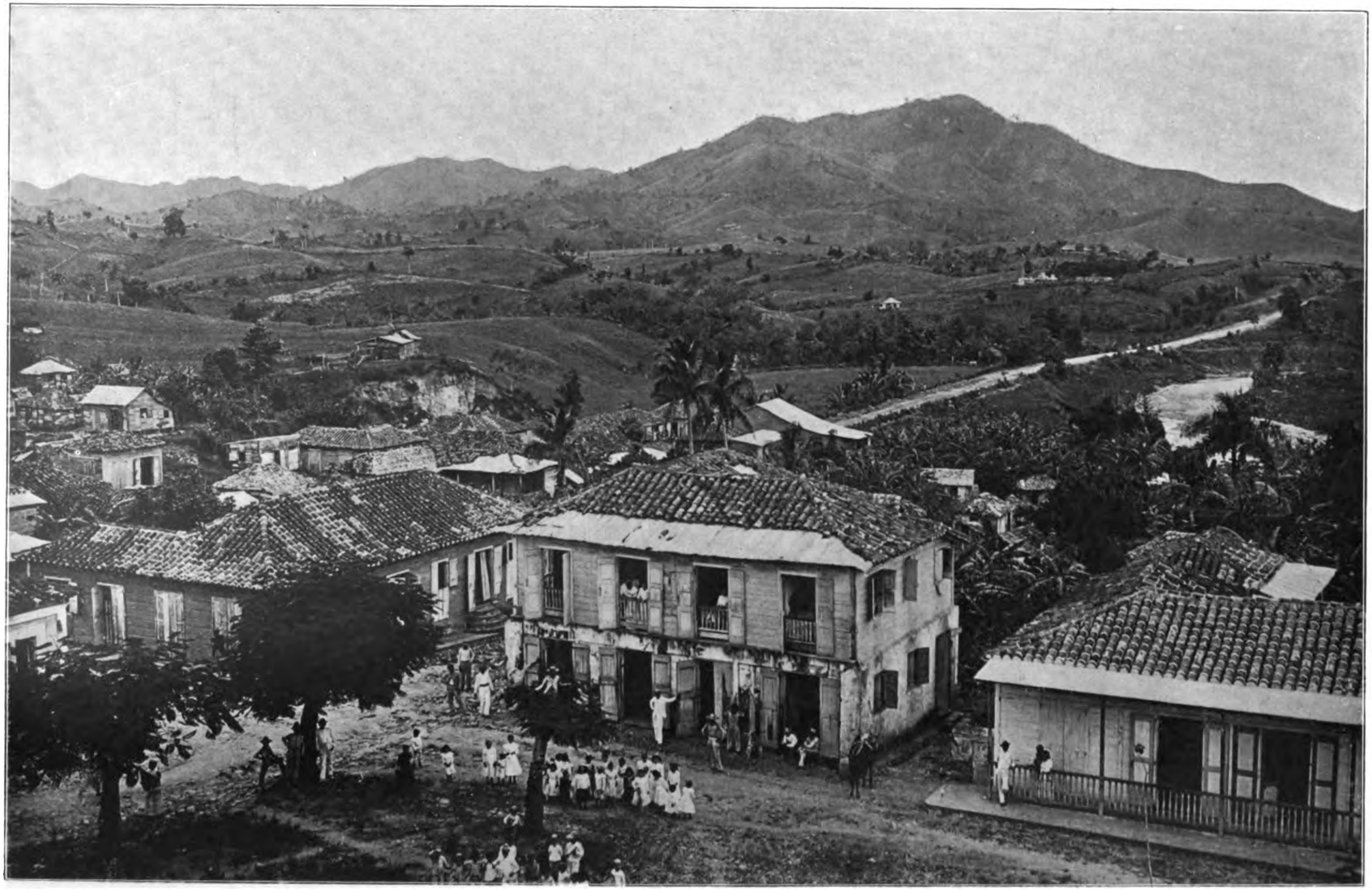


Plate V. Porto Rico. Typical mountain farming lands and village

the south. There are two good macadamized roads crossing the island, one from San Juan to Ponce, built under Spanish occupation, and one from Arecibo to Ponce, built since American control began. Several millions of dollars have been spent for roads since the American occupation. There are electric railways in San Juan and Ponce.

Under Spanish rule, landowners paid no taxes on their ownings and, as a consequence, there were many large tracts that were not cultivated but were devoted to grazing. Since American occupation, in 1898, the areas under cultivation have increased very greatly, especially those devoted to cane-growing. Thousands of acres have also been planted to the orange, pineapple and other fruits. The tax on land requires that it be put to some use or be put on the market, and there has been a tendency for lands to change hands. As the island is thickly populated, the prices are necessarily high, especially near good roads and towns. Coffee-lands, the highlands in the interior, are comparatively cheap, however, and a great many of them are mortgaged. Some of the mortgages have been handed down since Spanish rule. The change from the double to the gold standard caused great hardship to many of these planters, together with unfavorable crop seasons, and the fall in price of coffee. Land-titles are often defective and limits are not clearly defined. There are about 100,000 acres of public land which have been turned over to the insular government by the United States. Under the Spanish, most of the revenues of Porto Rico were raised by consumption tax. Under American administration, the revenues are raised by a property tax, which will probably result in more land being put under cultivation.

The industries of Porto Rico are necessarily agricultural, exports running a little over 90 per cent in agricultural products. The chief exports in point of value, are sugar, coffee, cattle, molasses and tobacco. All of the crops go to the United States except coffee, which is shipped largely to Cuba, France and Spain and elsewhere. Of the imports, rice is first, nearly all being shipped from New Orleans. Meats and flour are also largely imported. The agriculture of Porto Rico is very primitive, but since the American occupation great progress has been made. An agricultural experiment station has been established at Mayaguez, under the Hatch act, which has many lines of work under way. Many progressive planters have come from the United States, especially from Florida, and have taken up cane,- orange- and pineapple-culture. Some market-gardening has been attempted, and at present is a promising line of work. Better transportation is needed with the States, as the ships now coming to Porto Rico are not equipped for the handling of fruits and other perishable products. There is great need of capital for developing the resources, and also for enterprising men to handle the problems. Labor is plentiful and cheap, being readily obtained at forty to fifty cents per day.

The crops of Porto Rico.

The lowlands are devoted to the cultivation of cane, which, since the American occupation, has been very profitable, the sugar being admitted duty-free into the markets of the United States. These lands vary in price from $100 to $200 per acre. The interior lands are devoted largely to coffee, and range in price from $5 to $50 per acre. A great many acres are being devoted to growing citrous fruits and pineapples. No orchards were planted until the American occupation, but at the present these groves are coming into bearing and the outlook is promising.

Coffee is the leading crop of the island. The Porto Rican product has for a long time been sold in the markets of Cuba, Spain and France, and is an excellent variety of after-dinner coffee. It has not secured much foothold in the United States, as the public taste has not been cultivated for this variety. Since the American occupation, the established markets of Porto Rican coffee in France and Spain have been cut by the tariff. Efforts are now being made to reach the market in the United States with Porto Rican coffee and to grow those varieties that are acceptable to the American palate. Porto Rico is peculiarly adapted to growing coffee, especially on the high land of the interior, and it is not likely that any other product will supplant it in these regions. The more progressive planters that are using improved seed and have their nursery beds, and who give the very best attention to their crops, are making progress in this industry; but a great many of the planters are burdened with debt and are dis-

Fig. 123. Porto Rican landscape.—Valley of the Rio Grande.

couraged, and, as a result, their plantations will ultimately pass into other hands. The coffee tree in Porto Rico comes into bearing in about three years and attains its maximum at about twelve years. Under good conditions it will continue to bear to the age of fifty years. The average production per tree is under one pound, but, under proper care and cultivation, it can be largely increased. The coffee crop needs the attention, also, of the plant-breeder.

Cane-growing in Porto Rico is very profitable at present, it being especially favored by coming within the tariff law of the United States. There is a marked increase in the production per acre with improved methods. The old plantation mills have given way to large mills with the very latest improved machinery. Planters now find it more profitable to sell the cane to the large "centrals" than to grind it in their old-time mills and boil it in open kettles. The plentiful supply of labor has been of great advantage to the cane-growers, and this, being cheap, has been employed to a great extent in cultivating this crop. However, more improved machinery is being brought in and a number of steam-plows are in operation. The wooden plow has given way to the steel moldboard, and the importation of mules is supplanting the oxen. Planting of cane is usually done in the spring months, the cane being cut a year later. There is a tendency, however, for a longer period of growth, about fifteen months, known as "gran culture." The grinding season extends from January to July, a period of about six months.

Fig. 124. The open country of Porto Rico near the sea.—Vicinity of Martin Pena.

The areas suitable for tobacco-growing are somewhat limited, but this crop has not been very thoroughly exploited. The valleys of the interior, as a rule, are devoted to this crop, and leaf of very good quality is produced. A number of companies have been formed in the last few years for growing cigar tobacco and have been very successful. A great deal of wrapper tobacco is grown under cheesecloth, and the filler tobacco that has been properly fermented is of very fine quality. This is a crop that under the best conditions is very profitable in the island; but the methods of growing, and especially of curing and fermenting, are very crude, as a rule. There is a tendency for the curing and fermentation processes to pass into the hands of large manipulators, who buy from the small growers. In this way a more uniform and a better product is obtained, as the curing is kept under definite control.

Citrous fruits have been extensively planted in Porto Rico since American occupation. For several years large shipments have been made from the island, but they are of oranges that have grown wild. The plantations that have been set are just coming into bearing and, judging from the yield and quality of the fruit, this industry is a very promising one. There are some serious insect and scale pests, but with due care they can be kept under control. The planting of citrous fruits has been done altogether by Americans, a great many Florida men especially having come to the island for that purpose. Lemons and grape-fruits are also being planted to some extent, and both do very well. Next to the orange, the pineapple is being extensively planted. This fruit is largely canned on the island, but it is probable that the greater part in the near future will be shipped to the market in the States. There is a Porto Rican pine known as the Cabezona, which is very large and of good quality. This is the variety used by the canneries; some shipments have been made to the States. Care must be used in packing, as it does not stand shipment so well as some other pines. The Red Spanish is also being extensively planted, especially for shipment. This pine is not so large as the Cabezona, but is of delicious flavor and good keeping qualities, making it well-adapted for shipping.

The avocado, or alligator pear, is found in all parts of the island, and is a delicious fruit that is hardly known in the States. It is easily grown, but is a poor shipper; however, with the selection of better-keeping varieties and with improved shipping facilities, this fruit can undoubtedly be placed on the market in the States, and will be extensively grown. The native mango is found in all parts of Porto Rico, and is very plentiful in season. The fruit, however, is of inferior quality, and efforts are now being made to introduce the improved Indian mango. This kind is destined to become a very profitable fruit, from a commercial standpoint.

Bananas grow very readily in nearly all parts of the island, but at the present time form no part of the exports. They are consumed locally in immense quantities, and form a very large part of the food of the poor people. Their cultivation can be greatly extended.

Coconuts are grown near the seacoast, often being found on lands that are not adapted to any other purpose. A coconut plantation in bearing is very profitable. Cacao is grown to a limited extent and could very readily be made one of the leading industries of the island.

Small crops of rice, corn, sweet-potatoes, yams, bananas, tomatoes and melons are grown in all sections of the island for home consumption. These can be greatly improved by selection of better seeds and following better methods of culture. Potatoes are very largely imported, as are also onions; both can be grown on the island. Rice is raised on the highland, practically no lowland rice being grown.

Porto Rico was formerly heavily forested, but at present there are no woods of economic value, except a tree here and there. Some cedar is cut and brought down from the interior; all other lumber is imported. Coal is imported for the railways and electric plants, but the cooking is done on open charcoal fires. The hills are kept denuded of trees by the charcoal burners. The charcoal is brought down to the towns on mules and sold from house to house.

Live-stock industries.

The live-stock of Porto Rico consists of the descendants of animals brought in at an early date by the Spaniards. No care has been exercised in selecting and breeding this stock, and the result is a very inferior lot of animals. The horses are game, but small and incapable of much labor on the farms. Mules brought from the United States are used to some extent, but work on the plantations is largely performed by oxen. Considering the care that has been taken of them, the cattle are very good, some of them being of large size. They are, however, very slow in maturing, and the cows are very inferior as milch animals. A great many cattle are shipped to Cuba, where they are used for work animals on cane plantations, or are slaughtered for

Fig. 125. Huts as seen in the native villages of Porto Rico.

beef. The swine are very inferior, and for improvement the island must look to the importation of better animals from other countries. A great many goats are kept for producing milk. Sheep are scarce and not very thrifty. Poultry does well, though there is much to be desired in the improvement of the kinds, especially as regards size.

Future of agriculture in Porto Rico.

Porto Rico is destined to bear the relation to the United States that the Channel Islands now bear

Fig. 126. Plowing in the native Porto Rican fashion.

to Great Britain. Horticulture will be the leading industry, followed by stock-raising. When agriculture is more fully developed, products will be shipped into New York and other markets in kinds and at times to bring the highest prices. These products will consist largely of fruits, followed by vegetables; in addition, certain animal productions will be exported, especially poultry. The system of farming will be intensive and land will be made wonderfully productive.

The number of tourists coming to the island is increasing yearly, and land is being purchased for investment. It is probable that homes will be built by persons who desire to escape the rigors of the northern winters. The winter months of Porto Rico are delightful. The nights are cool and the days not excessively warm. The island is a place of great natural beauty, excelling in that respect the islands of Jersey and Guernsey. With the coming of capital and increase in the thrift of the inhabitants, Porto Rico will become prominent. The means of reaching the island from the eastern cities at present is inadequate, and ships are slow, requiring four to five days. With the increased production of fruits, faster ships will be put into the service that will make the trip from New York in three days. After passing Cape Hatteras, the trip from New York is through very delightful waters. At present, tours are arranged on ships which touch at San Juan and later make a tour of the island, affording a very pleasant way of obtaining a general view of Porto Rico. Trips into the interior may be readily made from the ports, over the excellent macadamized roads.

Since the American occupation, the island has not made the progress that was expected of it, but there now seems a turn in affairs that is leading to better things. The industries are getting on a paying basis, capital is receiving remunerative profits, and people of enterprise are coming in. The future seems bright for this newly acquired gem of the United States, set in the southern seas.

Agricultural education and organization.

The land-grant or Morrill act has not yet been extended to Porto Rico for the purpose of founding an agricultural school. There is a federal Experiment Station located at Mayaguez, which is conducted along lines similar to those in the States. It receives from the national funds $15,000 annually. However, instead of being under local control, it is administered through the Office of Experiment Stations, of the United States Department of Agriculture. There is no insular department of agriculture. The Commissioner of Interior has in charge a fertilizer law; there is also a law covering the importation of certain plants. There is an agricultural department connected with the University of Porto Rico, at Rio Piedras. Among the fruit-growers there is an organization called the Old Town Planters' Association, organized mainly for the purpose of furthering certain coöperative measures relating especially to shipping. The Experiment Station holds a number of farmers' institutes from time to time and also takes part in an agricultural society which has recently been organized.

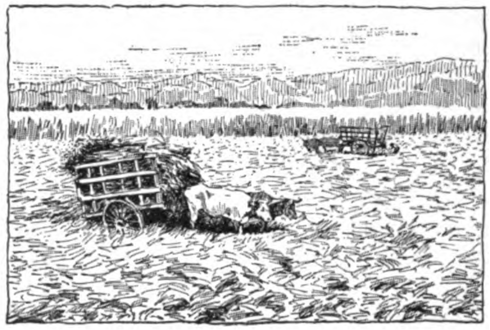


Fig. 127. Harvesting sugar-cane in Porto Rico.

AGRICULTURE IN HAWAII

By N. A. COBB

The two striking features of Hawaiian agriculture are the extreme variety of products; and, in contrast with this, the fact that since the islands began to play a part in the world's agriculture, the main dependence at any one time has usually been on a single crop. Sandalwood, wheat and potatoes for the California miners of 1849, coffee and sugar have each in turn been almost the sole export of importance, and yet no equally small area in the United States could produce so great a variety of crops. All tropical and nearly all temperate crops can be successfully grown. This is due to geographical position and a highly diversified conformation of volcanic origin. In some of the elevated districts the climate approaches that of the cooler parts of the temperate zone, while in other districts it is truly tropical. In general character, the climate is warm-temperate rather than subtropical. The greatest hindrance to the growth of cold-temperate crops is the unchanging character of the conditions of any one place. There is no such marked change of seasons as cold-temperate plants prefer.

The rainfall is derived from the moist trade-winds that blow three-fourths of the time from the northeast. High central mountains intercept these air currents, so that the windward districts have, for the most part, an abundant rainfall throughout the year (up to 30 in. per mo.), while the leeward shores are often somewhat dry, or almost rainless.

Geologically, the islands are of recent origin, and nearly all the useful plants have been introduced from older lands. This has led to striking results. All the plants that have been introduced by seed have arrived without the greater part of their natural enemies. The isolation of the country has in the past tended to preserve this happy condition, so that the vegetation was noticeably free from pests. Unfortunately, in more recent times the connection with other countries has been so intimate that a number of pests have been introduced. This has led to government inspection directed toward the exclusion of plant products likely to introduce any further evils. The fewness of the ports renders it possible to do really effective work of this character. It is doubtful whether any territorial funds are better spent than those devoted to this purpose, so long as the inspection remains thorough, impartial and unrelenting. The history of the pests that have been introduced is such as to lead to the belief that they find an unusual stimulus in the genial climate, so that they become exceedingly virulent.

There is a growing feeling that the agriculture of the territory should become more diversified, and already the forces are at work that will eventually make it so. The keynote of the work of the federal Experiment Station is diversification. The territorial Department of Agriculture has entered on a system of forestry that will do much to maintain, or even increase, the conservation of the water that must be forthcoming to render the leeward districts productive. Many of the sugar-planters realize the necessity, or advisability, of an increase in the variety of staple products, such as will give less predominance to sugar.

Of very great importance to Hawaiian agriculture is the preservation and extension of good forests. In the past, too little attention has been paid to this matter, but the increasing demand for irrigation water has at last opened the eyes of all to the necessity of water conservation through some system of forest management. A territorial forestry branch has been established as a division of the territorial Department of Agriculture. So far, its work has been largely confined to setting aside, by proclamation of the governor, territorial lands to be reserved as forests. In addition, certain other lands, with or without government advice and assistance, are being similarly set aside. In this

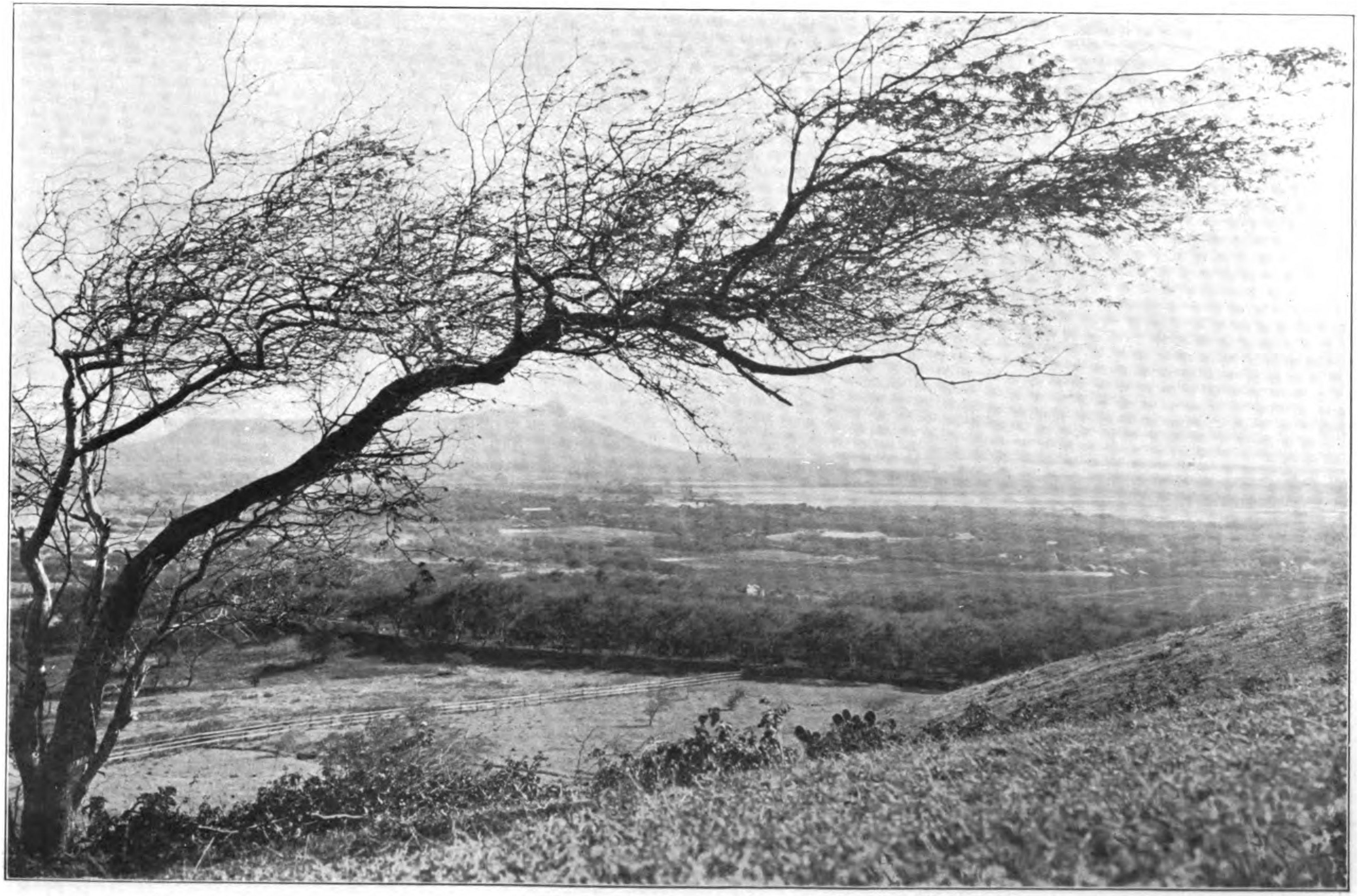
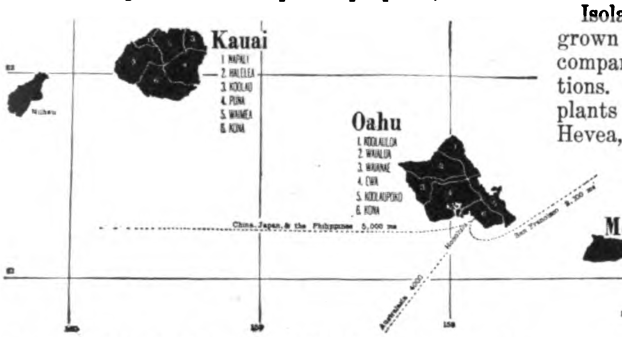


Plate VI Hawaii. Typical scene of rice fields, banana areas, small farms and algaroba forest; also the extinct crater of Diamond Head

way sixty thousand acres were reserved in 1904–5. The forestry division keeps on hand for free distribution for public or semi-public purposes, trees of



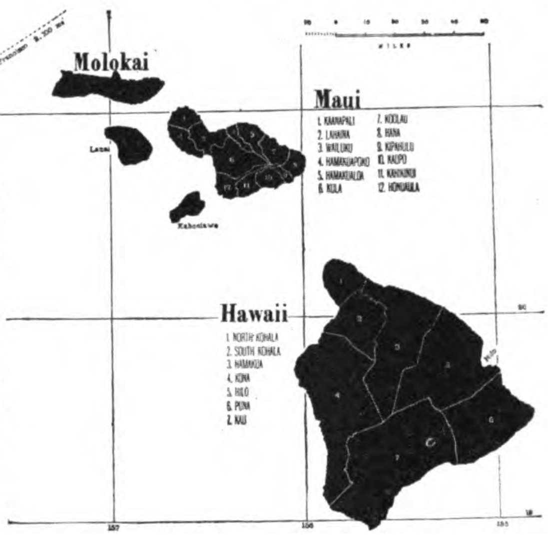


Fig. 128. Map of the Territory of Hawaii, to scale, showing latitude and longitude, location of the leading districts of each island, and the principal continental trade routes.

certain kinds, and collects local seeds of forest trees and sells the same at cost price.

In the past, forest plantations have been made by government agencies, notably on the island of Oahu, of eucalyptus, wattle and ironwood, all introduced from Australia. These trees have grown well and are remarkably free from pests. The wattle bark has proved to be of good quality, and the wood makes fairly good fence-posts, while the smaller growth is used by coopers.

The so-called algaroba (a species of *Prosopis* of the family *Leguminosæ*), is a tree of great importance in the drier parts of the territory (Fig. 136). It grows where few other trees will survive, and furnishes, especially during the dry summer months, thousands of tons of sweet, nutritious pods that are readily eaten by all sorts of stock. The pods are shed gradually, so that stock pasturing underneath is fed economically. As fodder for dairy cattle, the pods can be had in Honolulu at about $8.50 per ton, as against three to five times that amount for imported fodder of like feeding value. If dry, the pods may be stored for several months. Experiments are being made in grinding them, so that the seeds also may become digestible, by which means, it is hoped, the food value would be much enhanced. The indigestibility of the seeds causes the plant to be spread in the excreta of stock. The algaroba is the main source of firewood in some districts. Bees derive an abundance of honey from the blossoms.

Isolated specimens of rubber trees have been grown for some years. Recently, at least two companies have made efforts to establish plantations. Between fifty and one hundred thousand plants were set out on Maui during 1905, mostly Hevea, fewer Ceara, and possibly one thousand Castilloa. Most of the seed came from Ceylon and Singapore. The plantations are all young, and, though promising, have not as yet turned out any rubber.

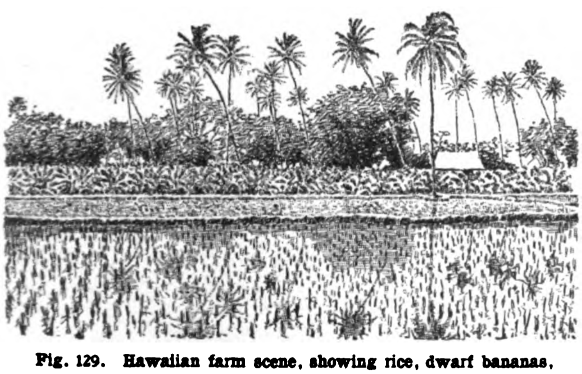


Fig. 129. Hawaiian farm scene, showing rice, dwarf bananas, coconuts and algaroba trees.

Sugar-cane. (By C. F. Eckart.)

Following the ratification of the reciprocity treaty between the Kingdom of Hawaii and the United States of America, a marked advance of the staple industry of these islands was manifested; labor was plentiful and comparatively cheap, prevailing prices were high, and conditions in general favored a rapid increase in the production and exportation of sugar.

In late years, however, the cost of labor has risen and the prices of sugar have decreased, and periods of industrial depression have at times affected the industry to a very large extent. The planters have had their prosperous years, and have also suffered from lack of labor, droughts, low prices for their product, and other conditions, during which times they have manufactured their sugar at such expense that there has been no profit. The unfavorable conditions, however, have been met with the progressive spirit of American farmers and business men, and improved methods of cultivation and manufacture have been adopted.

Twenty years ago the average yield of commercial sugar was about ten pounds per hundred pounds of cane, and the average

Fig. 130. Typical Hawaiian agricultural area,—always a valley, or a slope next the sea, and backed by mountains.—Rice, banana and taro fields are shown. The smaller areas in the middle of the picture represent rice-fields, the larger ones toward the left-center being banana plantations.

yield of cane per acre was about twenty-five tons. At the present time the average yield of commercial sugar is about twelve pounds per hundred pounds of cane, and the average yield of cane per acre is about forty tons.

There are now being operated fifty-two sugar plantations, with outputs varying from 500 to 39,000 short tons of sugar per annum. The great majority of these plantations are operated under separate management, while a few sell their cane to neighboring mills and plantations. These fifty-two plantations are all represented in Honolulu by agents, and, while most of them are joint stock companies, a few are owned by individuals. Forty-three of the plantations which are incorporated have 6,366 stockholders.

The sugar is shipped to San Francisco, and around Cape Horn by steamer and sailing vessel. From California it goes overland to the east. Under the United States shipping laws it is necessary that all sugar sent from the islands be shipped in American bottoms. The planters have been unable to obtain suitable American tonnage sufficient to carry all their sugar to the east around Cape Horn, and about one-fourth of the crop usually goes to San Francisco, and from thence overland at a rate very much greater than by all water.

The time taken in getting sugar to the market is from two to five months, owing to the great distance it has to be transported. In some instances, the sugar is shipped directly from the port of a plantation, but in most cases it goes to Honolulu, or Hilo, island of Hawaii, or Kahului, island of Maui, and from there is shipped to the United States. The shipment from the various island ports to Honolulu is accomplished through the Inter-Island Steam Navigation Company, which controls about nineteen vessels representing an American tonnage of 6,018.

The annual output of the islands since 1896 has been as follows:

Island	1896	1897	1898	1899	1900	1901	1902	1903	1904	1905
	Tons*	Tons	Tons	Tons	Tons	Tons	Tons	Tons	Tons	Tons
Hawaii	109,299	126,736	91,606	117,239	115,224	134,618	121,295	170,665	122,865	127,524
Maui	29,097	41,047	45,033	54,389	57,347	58,349	56,726	84,776	77,985	100,434
Oahu	35,782	28,929	34,181	45,820	53,625	99,534	107,870	121,066	102,019	123,095
Kauai	51,650	54,414	58,594	65,359	63,348	67,537	69,720	61,484	64,606	76,313
Total	225,828	251,126	229,414	282,807	289,544	360,038	355,611	437,991	367,475	427,366

* 2,000 pounds to the ton.

The yield of sugar for the Hawaiian islands for the crop of 1905 was 427,366 short tons, which quantity was harvested from an area of 95,444 acres. The following statements of yields show the relative production on irrigated and unirrigated plantations and for the islands as a whole:

YIELDS OF SUGAR FOR 1905

	Acres	Total sugar, tons	Yield per acre, lbs.
Hawaiian Islands . . .	95,443	427,366	8,955
Irrigated plantations . .	48,668	295,798	12,156
Unirrigated plantations .	46,775	131,568	5,625

While the average yield of 4.5 tons of sugar per acre appears high when compared with that of other sugar-growing countries, it is in a measure misleading, for the fact that the Hawaiian cane-crop takes, as a rule, from eighteen to twenty-two months to mature (thirty months are required on certain fields on the uplands of Hawaii) necessitates a considerable reduction in this stated yield before it can be brought into comparison with annual crops of other countries.

Reliable statistics have been recorded since 1895 showing the yields of sugar and acreage of all plantations in the group, and the increased production per acre between 1895 and 1905 may be seen from the following figures:

	1895	1905
Under cane—acres	47,399.5	95,443.5
Total yield of sugar—tons. . .	157,419.5	427,366.0
Yield of sugar per acre—lbs. .	6,472.0	8,955.0

This increased yield per acre during a period of eleven years may be attributed to several causes, which may be briefly stated.

A certain gain per acre has, without doubt, followed the planting of new lands. The total area of cane harvested in 1895 was 47,399.5 acres. Of these sugar lands, 23,945 acres, or practically 50.6 per cent, were dependent on rainfall for their water-supply, and 23,454.5 acres, or 49.4 per cent, were irrigated. In 1905 the area of cane harvested was 95,443.5 acres, of which 46,775 acres, or 49.01 per cent, were dependent on rainfall and 48,668.5 acres, or 50.99 per cent, received irrigation.

New lands taken over by the unirrigated plantations have been largely on the higher levels, where the soil is thinner and poorer as a rule, and the sugar yields, although at first good, are soon reduced after harvesting one or two crops, and become less than those obtained from the lower-lying areas. On the irrigated plantations, the new lands that have been added to the cultivated area have usually been richer than those under cultivation for some time, and much expansion has followed the opening of new sources of water-supply with the advantage of improved irrigation facilities. The gain in yields of the unirrigated plantations must be attributed almost entirely to improved methods of cultivation and fertilization and to the introduction of more thrifty varieties of cane; while in the case of the irrigated plantations a greater production due to new lands cannot be omitted as an important factor, along with the gain from progressive methods of cane-farming.

The profits accruing from the increased yields on the irrigated plantations have not always been commensurate with the increased production, owing to the large cost of waterway construction and of pumping. The cost of irrigation includes the installation of pumps, construction of ditches and reservoirs, tunneling, and the labor of applying water to the cane furrows. The expense incurred in the making of Hawaiian irrigation ditches may be conceived when the obstacles encountered in this line of engineering work are considered. The headworks of the Makaweli ditch, for example, involve twenty-nine tunnels of a continuous length of five miles, seven feet wide and seven feet high, excavated in the solid rock and built on a grade of eight feet per mile, which will give a daily capacity of over 60,000,000 gallons when running four feet deep (report of M. M. O'Shaughnessy). As regards the cost of pumping to higher elevation, Mr. O'Shaughnessy states: "To pump 10,000,000 gallons daily against a head of 300 feet with ordinary pumps and fuel in service will consume fifteen tons of coal, which at $8 per ton amounts to $120 for daily fuel expenses." Another engineer computes the average cost of lifting 1,000,000 gallons of water one foot, with coal as fuel, to be as follows:

Operating expenses	$0.081
Interest 6 per cent	.014
Depreciation 3 per cent	.007
	$0.102

With fuel-oil the average cost is reduced as follows:

Operating expenses	$0.053
Interest 6 per cent	.014
Depreciation 3 per cent	.007
	$0.074

About 5,000,000 gallons are used per acre in the growing of a crop, and this quantity is pumped to a maximum height of 550 feet.

A careful test conducted at the experiment station of the Hawaiian Sugar Planters' Association in Honolulu showed that without irrigation it was possible to obtain only 1,600 pounds, or less than one short ton of sugar per acre. This was with a rainfall of 32.5 inches per year. The largest of the irrigated plantations have a much smaller rainfall than 32.5 inches, and it would not be possible to harvest even the small acre-output indicated by the unirrigated cane at the experiment station. A yield of 1,600 pounds of sugar to the acre would not justify the expense of growing, harvesting and milling the same, and it is safe to say that were the sugar lands of this territory entirely dependent on rainfall, the 1903 crop would have yielded little more than 131,567 tons of sugar.

In accordance with the experience of planters in other sugar-growing countries, those of Hawaii have been obliged to maintain the yields in many localities by the substitution of more thrifty and hardier canes than the old standard varieties. The attention given to this subject on many of the plantations has undoubtedly helped to raise the acre-output. On Hawaii, the Lahaina cane, after having been grown for many years, was finally succeeded by the Rose Bamboo, which latter variety is now making way for a more vigorous cane, named Yellow Caledonia. In districts subject to over-copious rains or to excessive drought, where Lahaina and Rose Bamboo (in less measure) would show an occasional falling off in production, Yellow Caledonia, through its hardier characteristics, has

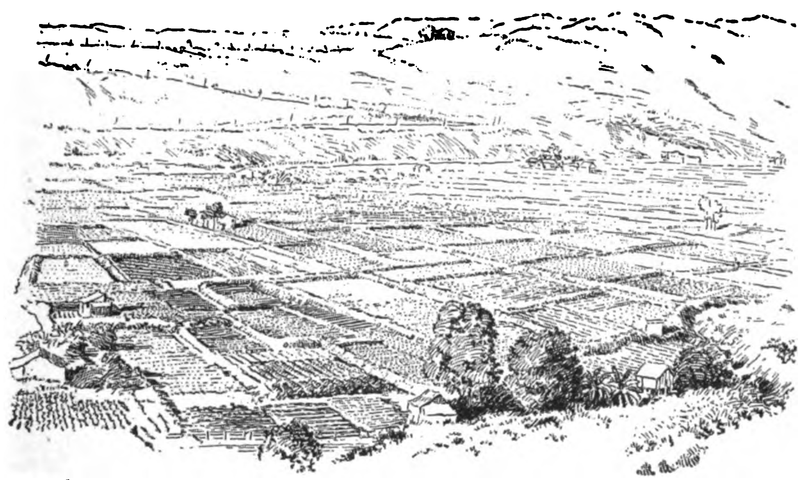


Fig. 131. A taro-growing valley, with vegetable plots, mango trees and bananas in the foreground.

maintained a favorable yield in less-favored seasons. On lands that had given out for Lahaina to such an extent that the cane made but a meager growth, this variety has yielded a profit to some plantations that would otherwise have taken off their crops at a loss.

Probably in no other cane-growing country does the subject of fertilization receive so much consideration as in the Hawaiian islands, and the study that has been given to this question by plantation managers has done much to raise the sugar yield per acre throughout the territory. The percentage of the various ingredients, as well as the forms in which they are applied in mixed fertilizers, are carefully considered with regard to climate and soil and, owing to the diversity of Hawaiian conditions, fertilizer formulas show wide variations in the various districts of the group.

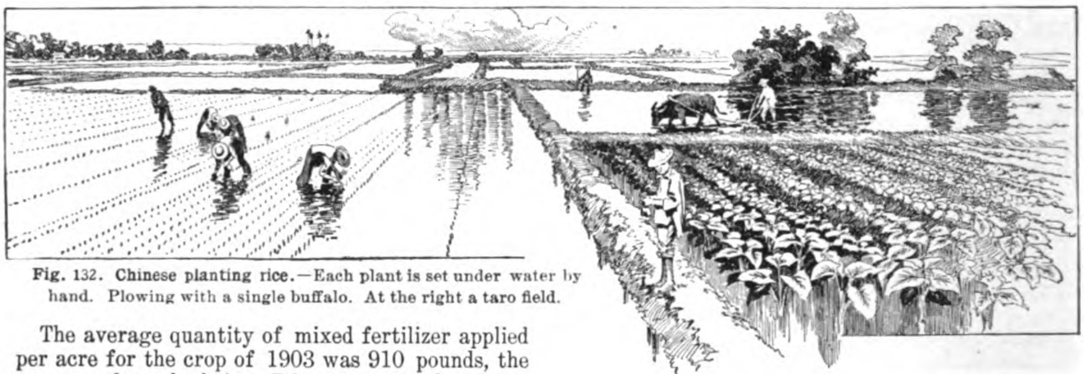


Fig. 132. Chinese planting rice.—Each plant is set under water by hand. Plowing with a single buffalo. At the right a taro field.

The average quantity of mixed fertilizer applied per acre for the crop of 1903 was 910 pounds, the average formula being 7.1 per cent phosphoric acid, 10.1 per cent potash, and 6.1 per cent nitrogen. The quantity of mixed fertilizer applied to the crop of 1903 was approximately 41,000 tons. The amount of nitrogen, phosphoric acid and potash used was as follows:

	Tons
Nitrogen in mixed fertilizer	2,501
Phosphoric acid in mixed fertilizer . . .	2,911
Potash in mixed fertilizer	4,141

About 6,000 tons of nitrate of soda, containing approximately 900 tons of nitrogen, were also used. These large quantities of the various fertilizing ingredients would have values somewhat as follows:

Nitrogen in mixed fertilizer	$750,300
Phosphoric acid in mixed fertilizer .	232,880
Potash in mixed fertilizer	393,395
	$1,376,575
Nitrogen in nitrate of soda	270,000
Total	$1,646,575

In addition to nitrate of soda, specially bought fertilizers, such as lime, ground coral, fish scrap, muriate of potash, tankage, and a mixture of nitrate of soda and sulfate of ammonia, were applied. The value of these latter materials, together with the cost of bagging, mixing of complete fertilizers, and transportation, would bring the total amount expended for fertilizers to somewhat over $2,000,000. Besides these fertilizers, which were bought, large quantities of stable manure, furnace ash, molasses and disintegrated mud press cakes were used, the exact quantity of which is not known.

On one plantation, as a result of careful fertilization, a gain of 100 per cent in sugar was obtained over unfertilized land. On very fertile soils, which respond less to fertilization, a gain of 20 per cent has been reached through the use of suitable fertilizing material.

Almost as much attention has been given to cultivation as to fertilization, and, owing to the diversity of methods, little can be said on the subject in a brief report of this nature. The most approved patterns of agricultural implements are used, and specially constructed plows, harrows and other machinery have been adopted in some instances. Steam-plows are used on many estates, and deep-plowing with moderate subsoiling are practiced when the depth of the staple will permit. In the rainy districts the cost of stripping, i. e., removing the dried leaves from the cane, and keeping down weeds, are large items in the expense of cultivation.

During the last several years the cane-fields of the Hawaiian islands have been afflicted with a serious pest, termed the leaf-hopper (*Perkinsiella saccharicida*), which on many estates has greatly reduced the yield of the 1904 crop. Since getting a foothold in the territory it has been noticed on seed cane arriving from Queensland and on Chinese cane imported for eating purposes by the Chinese population. It very probably was received originally from either Queensland or China, where it is not known as a pest, owing to the presence of natural enemies that keep it in check, or limitations exerted on its reproductive capacity through climatic causes. The root-disease, rind-disease and the so-called pineapple-disease all do considerable damage.

The low prices of sugar which have prevailed during recent years and the high cost of labor, together with the serious loss annually incurred from insect and fungous depredations, necessitate the utmost vigilance on the part of plantation managers to determine sources of loss in the mill and fields, and through technical skill in the one instance and more progressive methods of farming in the other, to combat the tendency toward reduced profit which has been more strongly felt from year to year.

Other Hawaiian crops.

Second in importance to sugar-cane, but a very long way behind it, is rice, which has been grown since about 1860, always by Chinese using oriental methods. In all the islands most of the suitable lands have been taken up, so that no very great expansion of the rice area is possible; but with improved methods, there is no doubt the industry could be made more profitable. Modern methods of machine-plowing, sowing, irrigating and harvesting are all applicable. Instead we see the plodding Chinaman digging up the soil by hand, or scarifying it with the aid of an oriental buffalo, or, at most, using a single furrow plow. Every plant is set by hand and the reaping is done with sickles. Threshed out on wooden or cement floors by horses' hoofs, the grain is first winnowed in the wind, after which it is decorticated in crude mills driven by overshot water-wheels. It is finally cleaned in a simple mill or in the wind. The two crops of a good season yield about ten million pounds of excellent rice, of which formerly more than half was available for export, but less, recently. Most of the rice used in the territory is locally grown. A small quantity arrives from the southern States and from Japan, the territorial Japanese, apparently from patriotic motives, consuming considerable quantities of Japanese rice. The present retail price varies from three and a half to four dollars per hundred-pound sack.

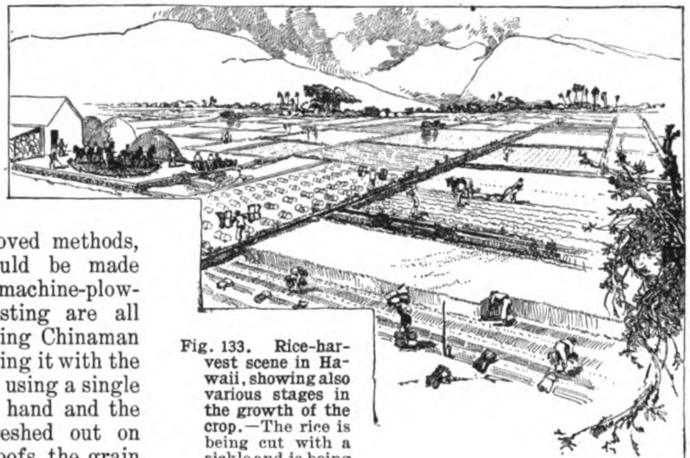


Fig. 133. Rice-harvest scene in Hawaii, showing also various stages in the growth of the crop.—The rice is being cut with a sickle and is being bound by hand with rushes. A woman gleans while she carries a child on her back. The sheaves are being carried to the threshing floor with the aid of Chinese shoulder-poles. Horses and mules are shown, treading out the grain. New fields are being immediately plowed for the second crop. Two crops are grown in the year.

The coffee industry, third in rank, is permanently established, but is languishing at present owing to low prices. The largest crop yet raised totaled about three million pounds, valued at about a quarter of a million dollars. The crop is grown on all the islands, but principally on Hawaii, where two-thirds of the total product comes from about 5,000 acres in the district of Kona. "Wild" coffee yields 700 to 800 pounds per acre. Topped trees yield about double, and, if properly manured and tended, are said to remain thrifty. It is said to cost seven and one-half cents a pound to grow coffee that brings the grower ten cents. The cost of growing is somewhat greater in the Hamakua district, also on Hawaii. The value of the coffee shipped in 1904 was $184,180.

Fig. 134. Bananas as grown on low land near Honolulu.

Taro (Colocasia) was the main source of food for the native Hawaiians before the advent of civilization, and even now it constitutes a principal part of their food. The white population find it nutritious, and palatable after a period of initiation. The plants grow in watery places, though upland varieties exist. These latter thrive only in rainy districts. The tops of the corms are set in or very near the water, and in somewhat over a year the crop is ready to harvest. Baked or boiled, the roots have the flavor of chestnuts. The tops, cooked as greens, slightly resemble spinach. The root, when slightly cooked and ground and allowed to ferment with water, forms poi, the native food, which is eaten as a pasty mass. Recently the cooked and dried root of the taro has been converted into flour and put on the market dry. This new industry has, to some extent, increased the growing of the plant.

Over one hundred species of fruit are successfully grown, though for the most part in small quantities. A correct idea of the facts is most briefly conveyed by naming the very few fruits that cannot be, or at least are not, grown. Currants, gooseberries, raspberries and blackberries are not successfully grown. Peaches and cherries are not grown to any extent, though a few peaches are to be found. Probably these and apricots can be grown after the necessary experience has been gained. From this it will be seen that all the fruits of the torrid zone, and all but those of the colder parts of the temperate zone are grown. Nevertheless, the bulk of the grapes, apples, pears, stone fruits and citrous fruits are imported from California. Of the immense number of fruits grown, the following deserve mention as having attained to some importance in trade:

Some of the numerous species of bananas, the leading export fruit, are probably indigenous, but most have been introduced. Among the latter is the *Musa textilis*, furnishing manila hemp. However, this fiber is not yet manufactured. The China and Brazilian bananas are those principally grown, more particularly because they stand the winds well. Bluefields banana plants now exist in the territory and will shortly be in the hands of practical growers, who are nearly all Chinese. The year 1904 saw nearly 100,000 bunches exported, valued at $128,240. An even larger number is consumed locally, of which a considerable proportion are varieties specially suitable for cooking.

Pineapples are gradually increasing, the number at present growing being about three million, of which fully three-fourths are on the island of Oahu. A few hundred thousand are consumed locally, from 150,000 to 200,000 are sent fresh to the main land, while the several canneries located on the plantations shipped in the year 1904, for example, about 20,000 cases of tinned pineapple to the United States. The Smooth Cayenne and some other varieties attain a very fine quality.

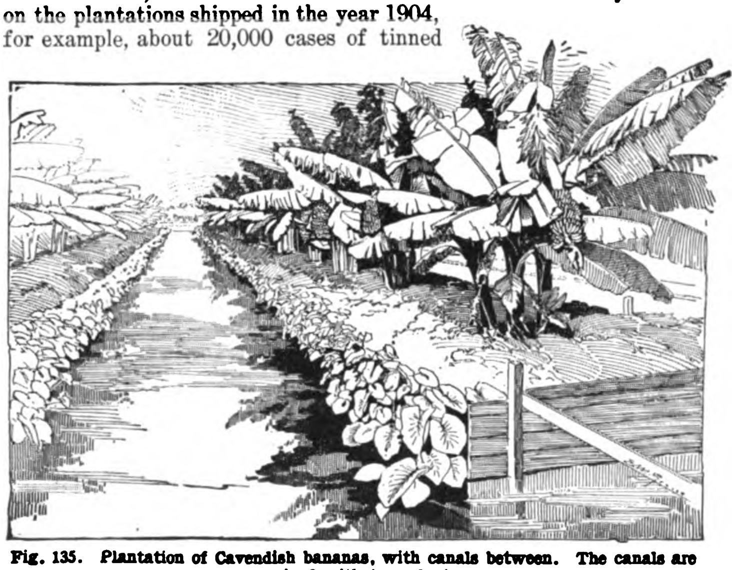


Fig. 135. Plantation of Cavendish bananas, with canals between. The canals are margined with taro-plants.

The mango tree flourishes and bears profusely, in spite of a number of serious diseases. There are, however, very few grafted trees. Therefore, the fruit is of very irregular quality. The best is equal to that found anywhere, and if it were systematically grown and pains were taken to supply a uniform quality, there seems no reason why it should not find a regular and profitable market in San Francisco and other mainland ports.

The alligator pear, or avocado (*Persea gratissima*), is now receiving additional attention. A number of varieties are grown and there seems to be a definite attempt to grow a uniform and improved product. A small number are sent regularly to San Francisco, but difficulties are so great that the business is very small.

Papaia, or pawpaw, is very generally grown, there being hardly a garden without one or more trees. Plantations of considerable size occur. As the fruit does not carry well, almost none is exported. Visiting passenger steamers take a few for immediate consumption on board.

Concord and Isabella grapes are grown the year round on a small scale by the Portuguese. These retail at ten cents a pound. These Portuguese vignerons also grow the few figs that are sold fresh. No figs are dried.

Vanilla has been grown as a curiosity for many years. Within the last few years capital has been invested for its production on a commercial scale. It has been demonstrated that the plant can be grown so as to produce a good quality of bean, especially on the south and west sides of the island of Hawaii, in the warmest part of the territory. Here the temperature, rainfall and tree-growth necessary for the best growth of the vine are all to be found. The price of coffee having to some extent recently interfered with its cultivation, it has been suggested that some of the coffee trees it is proposed to abandon may be used as a support for vanilla vines. The vanilla is subject to diseases, some of which have been imported. The present acreage is very small. It is estimated that five acres will afford support for one family.

The sisal hemp does remarkably well on some of the more arid and stony lands of the leeward districts. Such lands are unsuitable for cane, and capital to the extent of $75,000 has been invested in the industry, most largely on Oahu, but also on most of the other islands. The quality of the fiber is excelled perhaps only by that of manila. The present cultivated area is about fifteen hundred acres.

There is a plantation of castor-oil plants, one hundred acres in extent, that has been a commercial success. Good oil has been extracted and sold on the mainland.

Very little tobacco is grown, though it has been known for a long time that the crop thrives under Hawaiian conditions. The curing of the past has been defective, or at least unsuitable, and this accounts for the poorness of the product. Recent experiments render it very probable that first-class results are possible in tobacco-culture.

The climatic conditions are most favorable to the growing of many kinds of vegetables. Potatoes, cabbages, beans, corn, tomatoes, kohl-rabi, sweet-potatoes, lettuce, eschalots, radishes, egg-plants, carrots, beets, and many other kinds do well in the proper districts. In short, all the roots and tubers and vegetables flourish except those peculiar to the colder parts of the temperate zone.

Live-stock in Hawaii.

The number of cattle in the territory is estimated at 140,000, the number of sheep at 95,000. Good horses are reared. A few mules are bred, but most are imported from the mainland. Recently some efforts have been made to introduce fresh breeding-stock from abroad and with very promising results. The breeds of cattle that find most favor are Hereford, Shorthorn, Angus, Devon and Holstein, especially the first named. A limited amount of dairying is done near the towns, but much of the butter and practically all of the cheese is imported. Sorghum is a favorite green feed and grows very well, ratooning so that a number of cuttings can be made from one sowing. The grasses are fair in quality, especially some of the introduced ones, but much remains to be accomplished in this line, especially in the introduction of forage grasses suitable for the drier districts. Lucerne is grown with success.

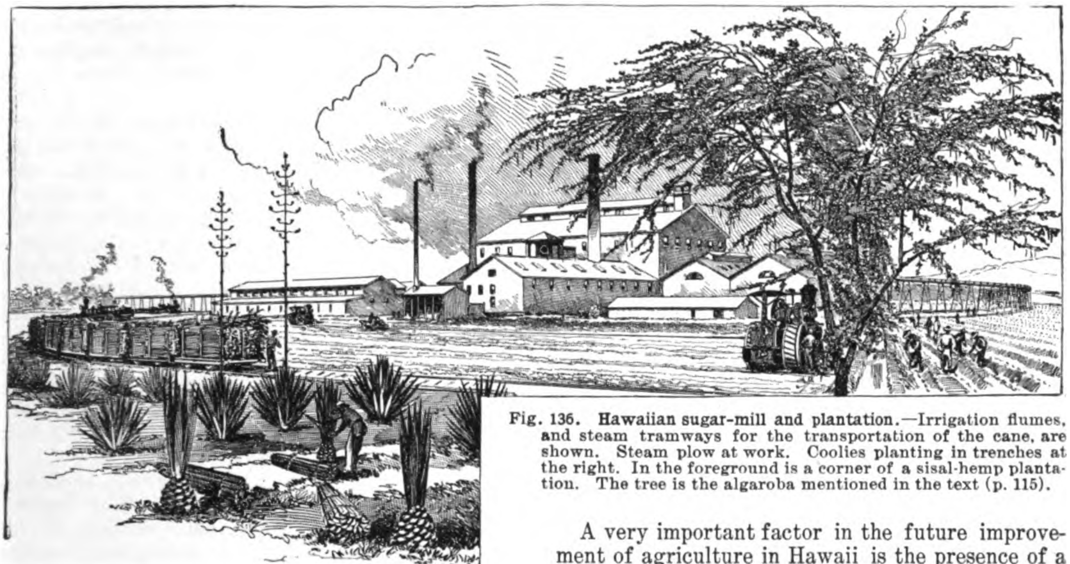


Fig. 136. Hawaiian sugar-mill and plantation.—Irrigation flumes, and steam tramways for the transportation of the cane, are shown. Steam plow at work. Coolies planting in trenches at the right. In the foreground is a corner of a sisal-hemp plantation. The tree is the algaroba mentioned in the text (p. 115).

Nearly all the beef and mutton consumed is grown locally. There were $100,000 worth of hides and wool exported in 1904.

With some special care, rendered necessary by the diseases peculiar to the climate, fowls do well. Many breeds are raised, the smaller and thinner-feathered breeds doing best. Many eggs are still imported. Great numbers of ducks are raised on special duck-farms by the Chinese.

The outlook.

There can be little doubt about the future of agriculture in Hawaii. The population is bound to increase and the local market therefore to expand. Many foodstuffs at present imported can certainly be grown at home with advantage, and the increasing Americanization of the territory, that must be an unalterable policy of the government, will see to it that no opportunity of this kind is neglected. The introduction of machine methods cannot be long delayed in a number of industries that are now prosecuted in a primitive fashion. These factors combine with many others to make the future look promising.

A very important factor in the future improvement of agriculture in Hawaii is the presence of a number of flourishing agricultural institutions recently established. Among these must be mentioned the Experiment Station of the Hawaiian Sugar Planters' Association (eighteen officers), the territorial Department of Agriculture (nine officers), the Federal Experiment Station (eight officers), and the Agricultural Department of the Kamehameha School (three officers), all having headquarters at Honolulu, and extending a beneficent influence throughout the territory. The Sugar Planters' Experiment Station, as its name would indicate, is devoted to investigations bearing on the problems of sugar production. The Territorial Board of Agriculture and Forestry has the enforcement of the inspection laws of the territory relating to the importation of plants, live-stock inspection, the studying of problems of forestry, and the propagation and distribution of valuable plants. The federal Experiment Station devotes its energies to the study of problems of diversified agriculture, conducting experiments with tropical fruits, rice, sisal, rubber, tobacco, fungous diseases and insect enemies of economic plants, bee-keeping, silk culture, introduction of grasses and other forage crops, the feeding value of Hawaiian-grown fodders, soil studies, vegetable-growing, and other subjects, the object being to supplement the agricultural practices now existing in Hawaii. It is doubtful whether any other equal number of American citizens is so well served in the way of agricultural experiment stations.

AGRICULTURAL STATUS OF THE PHILIPPINES

By F. LAMSON-SCRIBNER

The land area of the Philippine islands is approximately 128,000 square miles, or a little more than the combined areas of all the New England states, New York and New Jersey. The islands of Mindanao and Luzon, which are the largest in the group and of nearly equal size, are each over 40,000 square miles in area; nine have singly an area of over 1,000 square miles, thirty-one exceed 100 square miles each, while there are many hundreds of others of lesser extent. The surface is much broken, the larger islands being traversed with more or less well-defined mountain ranges reaching an elevation of 3,000 to 5,000 feet, with occasional peaks of 8,000 to 10,000 feet altitude. There are twenty more or less active volcanoes, and earthquakes are frequent in parts of the archipelago. The islands are well-watered by many streams and rivers, several of the latter affording means of transportation for long distances from the coast.

Fig. 137. The Philippine islands.

Climate and soil.

Lying entirely within the torrid zone, between the fifth and twenty-second degrees north latitude, the climate is everywhere tropical, but it is rarely excessively hot, and the range of temperature is within narrow limits. In the vicinity of Manila, the mean annual temperature is about 80°, that of the month of May, usually the hottest month, being 84°, while the average mean for January is 77°. The average diurnal range of temperature near the coast for the year is only 11°. In the interior valleys and on the higher mountains this range is somewhat greater; in some of the mountain districts, the climate is particularly delightful, and many plants of the temperate regions can be grown with success.

Generally speaking, there are two well-marked seasons, a wet and a dry, though there are certain sections where the rainfall is very uniform throughout the year. At Manila, and usually along the western coasts, from November to June, or during the northwest trade-winds, the season is dry, while during the southwest monsoon, or from June to November, is the rainy season. Along the Pacific coast, east of the mountains, these dry and wet seasons are reversed. During the monsoon period, typhoons occur that are sometimes so severe as to cause great damage to crops.

The rainfall is largely controlled by the physical characters of the country, and varies from about fifty inches to over one hundred and twenty inches, being heaviest on the slopes facing the Pacific. The relative humidity of the atmosphere is high at all times, while during the rainy season it is practically saturated with moisture; and the consequent rapid development of mold causes much annoyance and has to be carefully guarded against. The continuous heat and excessive moisture are strong factors in the rapid and luxuriant growth of all vegetation which prevails in these islands. With water lacking, the richest soils yield but a dwarfed and stunted growth. Where the dry season is at all pronounced, a water-supply by irrigation is essential to the profitable production of many of the cultivated crops.

The soils vary greatly in composition and fertility. Those consisting chiefly of volcanic ash and the alluvial deposits along the river-bottoms are very rich, in some cases of apparently inexhaustible fertility. Such are the abaca soils in Albay province, in the vicinity of the volcano Mayon, and the tobacco lands in the Cagayan valley. The rich, heavy loams along the rivers, composed largely of silt with a large percentage of organic matter, will always be the most productive, and, excepting perhaps for the growing of special crops, will always command the highest price. There is a great deal of land that has become unproductive or depleted through continuous cropping and bad cultivation. The Filipino farmer rarely applies fertilizers to his lands, and in most places the use of manure or the value of crop rotation and good tillage are unknown. Thorough cultivation and the employment of green-manures will doubtless render productive many of the lands that are now wholly unremunerative.

A systematic study of Philippine soils was begun

Plate VII. Philippines. Preparing for rice, with water buffalo by the Insular Bureau of Agriculture in 1902, and reports on the abaca soils, the soils of Batangas province and of other provinces in Luzon, including the tobacco soils of northern Luzon, have been published in the reports and bulletins of that Bureau. A map showing the location and character of the Batangas soils was published from data gathered by a special survey, the first ever made within the tropics.

The agricultural industry in the Philippines.

There are 815,453 farms in the islands of an estimated area of 6,987,076 acres, the average size being only 8.57 acres, against 146.6 acres in the United States. Nearly 50 per cent are less than two and one-half acres in extent, and very many are no larger than ordinary kitchen-gardens, but under slight cultivation they contribute materially to the comfort and subsistence of their owners. The sugar plantations, and occasionally the rice and hemp farms, are of much greater extent, sometimes embracing thousands of acres.

One and a quarter million of farmers and farm laborers own or manage and work these farms, yet only about 45 per cent of their area is cultivated, and their total area is less than 10 per cent of the area of the islands. La Laguna province in Luzon stands first in the extent of its agricultural lands, over 53 per cent of its area being in farms, while in Benguet province it is less than 0.1 per cent. In addition to the number of farmers and farm laborers above noted, there are over three thousand florists and nearly fifteen thousand herdsmen, who may be classed as agriculturists.

Agricultural products supply 94 to 95 per cent of the total value of all exports, derived almost entirely from the four staples, hemp, sugar, tobacco and copra, more than 65 per cent arising

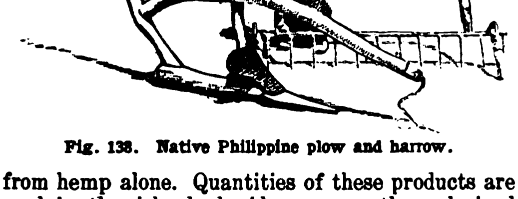


Fig. 138. Native Philippine plow and harrow.

from hemp alone. Quantities of these products are used in the islands, besides many others derived from the farm and garden, some entering into the inter-island trade or commerce between provinces, others used wholly to supply the immediate wants of the producer. Among these products are rice, corn, sweet-potatoes, cotton, maguey, gabe (*Colocasia esculenta*), bananas, and a great variety of other native and introduced fruits, vegetables

Fig. 139. Bringing zacate hay to market in the Philippines. (See page 131.)

and fiber-plants, fully enumerated in the Philippine Census Report (IV. pp. 117 to 176).

About 80 per cent of the farms are worked by the owners of the land; less than 2 per cent are cash tenants, while about 16 per cent are share tenants, occupying holdings for which rental is paid by a part, usually one-half, of the crop. When labor is employed on the larger farms and plantations, the laborers usually live with their families on the place, in houses furnished them by the owner, who also furnishes their food of rice and fish in addition to their wages, paid either in money or in a share of the crops produced. The method varies in different provinces, as does the amount paid. In Pangasinan, nearly all work is done on shares, payments being made or any advances returned when the crops are harvested. In Albay, the hemp-workers receive one-half the amount of fiber they produce per day, which may vary in value from four to eight pesos; ordinary laborers receive one peso (the Spanish dollar) per day. In Iloilo province, farm laborers receive one peso per week, a place to live, and two rations per day. In La Laguna province it is customary to pay the laborers on the coconut plantations one-fifth the crop. In Pampanga, most of the laborers are tenants and work the fields on shares. On the sugar plantations in Negros Occidental, the overseer is paid $22 per month, the foreman $11, the mill-hands $4 and the field-hands $3, and board, which usually costs fifty cents a week per man. In Oriental Negros the ordinary farm laborer is paid twelve cents Mexican per day, with two meals, which generally consist of cooked rice with a little salted or dried fish and occasionally fresh vegetables. Generally speaking, the price of farm labor ranges from forty cents to one dollar Mexican per day. Wages have advanced 50 per cent or more, in some localities, since American occupation. The Insular Bureau of Agriculture has never experienced any difficulty in securing all the laborers needed on its experiment stations and farms, and, for the most part, this labor has been satisfactory, as the natives are quick to learn how to handle American farming tools, and make excellent teamsters.

The better quality of rice land which can be easily irrigated, is valued in Pangasinan from $150 to $200 Mexican per hectare; in Albay, rice lands are valued at 50 to 80 pesos per hectare, and well-planted hemp lands near the main roads, 100 to 150 pesos per hectare; in Occidental Negros, the value of land varies from 25 to 100 pesos per hectare. Lands planted to coconuts, coffee, cacao or hemp are often sold at prices agreed on for each plant or tree. In general, prices for land are based more on the financial necessities or sentiment of the owner than on the real producing power of the land itself.

The farming implements of the Filipino are of the simplest and crudest character, the bolo (a long knife) being the implement in most general use. The bolo is employed on every occasion and for a great variety of purposes, from the felling of trees and clearing of land to the making of toothpicks. The single plow, drawn by the slow-moving carabao, or water-buffalo, guided by a rope attached to his horns or nose, is a one-handled wooden affair with a straight beam and practically no mold-board. The plow points are usually of iron, but so made that they do little more than scratch the surface. Working with this outfit, plowing is a slow and tedious process. In preparing rice lands, the plow is worked under water, simply stirring up the mud in its course. After plowing, the land is gone over with a kind of harrow, consisting of a single bar with a number of long, sharp teeth. Wooden harrows, made of several sections of bamboo stems, a few inches of the branches being left for teeth, are used on the uplands. These implements, with the bolo, constitute the outfit of the majority of the farmers.

The principal agricultural products.

With the exception of rice, sugar-cane, tobacco and corn, all crops grow without even the care of planting, often to the extent of fully supplying the simple wants of the natives. This liberality of the soil has naturally led to indolence and apparent lack of thrift difficult to overcome and little understood by those living in less-favored climes. Of the wild products, hemp and coconuts are by far the most important, and both are extensively cultivated. The principal crops of the several provinces are enumerated below:

Albay	Hemp, rice, coconut, corn, cacao, coffee.
Antique	Rice, corn, sugar-cane.
Bataan	Rice, sugar-cane, corn.
Benguet	Rice, corn, coffee, potatoes.
Bohol	Rice, sugar-cane, corn, tobacco, hemp, copra.
Bulacan	Rice, sugar-cane, sweet-potato, gabe, tobacco.
Cagayan	Tobacco, rice, corn, nipa.
Camarines	Rice, hemp, corn, coconut, sugar-cane, coffee, cacao.
Capiz	Rice, corn, sugar-cane, coconut, hemp, tobacco.
Cebu	Rice, corn, sugar-cane, tobacco, hemp, coconut.
Cotabato	Rice, corn, hemp, sugar-cane, coconut.
Cavite	Rice, sugar-cane.
Davao	Hemp, rice, corn, coconut, cacao, tobacco, coffee.
Ilocos Norte . . .	Sugar-cane, coconut, rice, maguey.
Ilocos Sur	Rice, corn, indigo, sugar-cane, cotton, tobacco.
Iloilo	Rice, corn, tobacco, sugar-cane, hemp.
Isabela	Tobacco, rice, corn.
La Laguna . . .	Coconut, sugar-cane, rice, hemp.
Leyte	Hemp, rice, corn, coconut, sugar-cane, tobacco.
Lepanto Bontoc . .	Coffee, cacao, rice, tobacco.
Misamis	Corn, rice, coconut, hemp, tobacco, cacao, coffee.
Mindoro	Coconut, hemp, rice.
Negros Oriental . .	Sugar-cane, hemp, rice, corn, coconut, cacao.
Negros Occidental .	Sugar-cane, rice, corn, coconut, cacao, hemp.
Neuva Ecija . . .	Rice, corn, sugar-cane, coffee, cacao, tobacco.
Pampanga	Rice, sugar-cane, corn.
Pangasinan	Rice, sugar-cane, corn, coconut, nipa, cacao, tobacco.
Paragua	Rice, copra, tobacco, hemp.
Romblon	Tobacco, hemp, rice, corn, coconut.
Rizal	Rice, sugar-cane, mango, banana.
Sámar	Hemp, rice, coconut.
Sorsogon	Hemp.
Surigao	Hemp, rice, cacao, coconut, corn.
Tarlac	Rice, sugar-cane, corn, tobacco, cacao.
Tayabas	Hemp, rice, coconut, corn, sugar-cane.
Union	Rice, sugar-cane, tobacco, corn, coconut, cacao.
Nueva Vizcaya . .	Rice.
Zambales	Rice, tobacco, cotton, sugar-cane, corn, maguey.
Zamboanga	Rice, coconut, corn, sugar-cane.

The culture of rice.

Rice is the staple article of food of the native Filipino, being to him what bread is to the American. Its cultivation antedates the Spanish sovereignty, and at one time large quantities were exported to China. During recent years, however, the production has fallen off to such an extent that large imports have had to be made in order to prevent actual famine. In 1904, the amount imported was valued at over eleven million dollars. This was reduced the following year to about seven million, indicating a marked improvement in the industry. The area of good rice lands is so extensive that, with modern methods of cultivating and handling the crop, the production ought to meet all local demands and furnish a large surplus for revenue.

About 150 varieties of rice are recognized in the Philippines, distinguished primarily into lowland and upland rice, the several varieties varying in the size, shape and color of the grain; some varieties are more prolific than others; there are early and late varieties, and there is great difference in the quality of the grain. Mimis yields a white transparent grain of excellent flavor, and the grain of Malagquit possesses a decided glutinous quality, so that cakes and pastry may be made from the flour. There is also a difference in the keeping qualities, it being impossible to keep the ordinary kinds in storage for more than two years, while that known as Binanquero rice will keep in good condition for five years.

Fig. 140. Preparing the land for rice in the Philippines; transplanting.

Lowland rice is sown thickly in a carefully prepared seed-bed surrounded by a low dike to hold the water, which is immediately turned on after seeding. These seed-beds are from one-twentieth to one-thirtieth the size of the field to which this seed rice is to be transplanted. The fields are diked to retain water, the number of dikes varying according to the contour of the land. When the ground is thoroughly wet or even covered with a few inches of water, it is plowed and harrowed until it is thoroughly stirred up into a soft homogeneous porridge-like mass. The young seed rice, when about 10 inches high, is transplanted to these fields, three or four plants being thrust into the mud by hand, the sets being six to eight inches apart in continuous rows which may be nine inches apart. Fig. 140. It costs about one dollar to take up and transplant one acre. The transplanting is usually done by women and the work is carried forward very rapidly. The fields are now kept flooded until the grain is about ready for harvest, which takes place in November or December. Two crops are sometimes grown during the year, and when this system is practiced the first transplanting occurs in April and the harvest in September, the second planting in October, harvested in February. In harvesting, the heads are cut off one at a time and tied into small bundles, which are left in the field for a short time and then stacked where they are to be threshed. The threshing is done by the trampling of horses or cattle, the grain being laid in heaps over a smoothly prepared surface of ground. Sometimes the grain is trampled out by men, or it may be beaten out by striking the small sheaves over a stone or a fixed piece of bamboo. The processes of winnowing and hulling are most primitive, such as have been practiced in the East for centuries. The yield varies from 1,000 to 4,000 pounds per acre. Lowland rice is always more productive than the upland-grown, but the latter is considered richer and better flavored.

In 1903, the Insular Bureau of Agriculture secured a tract of land in Tarlac province and undertook the cultivation of rice on quite an extensive scale, importing from the United States a full line of farming tools and machinery for conducting the work according to modern methods. Disk and gang plows and spring-tooth harrows were employed in breaking and preparing the land, using horses and mules with native teamsters. The seed was planted with a drill, and a combined harvester and binder was used in gathering the crop. The imported steam thresher was used successfully, and, aside from threshing the farm crops, 35,000 bushels were threshed for neighboring planters, who were quick to see and appreciate the advantages of this method over the slow and wasteful practice of trampling out the grain with horses and carabao.

Manila hemp. (Figs. 142, 143.)

Abaca, or manila hemp, is the most important agricultural product of the islands from a financial standpoint, supplying, as it does, over 65 per cent of the total value of exports. One hundred and twenty-eight thousand, five hundred and sixty-four tons of the fiber, valued at $22,146,241, were exported in 1905. Of this amount, 72,196 tons

Fig. 141. Native rice-mill, Philippines.

were shipped to the United States, where it is used for making cordage and twine. A great deal is used locally, not alone for ropes, for the finer grades are manufactured into textiles known as sinamay and tinampipi, the latter a cloth of very delicate texture. These are used by natives for making clothing.

Abaca, the native name for *Musa textilis*, a species of the banana family, grows wild throughout the archipelago, being most abundant between the parallels six and fourteen north. Its profitable production is limited to those sections in which the rainfall is very evenly distributed throughout the year, even a few weeks of continuous dry weather causing serious injury to the plants. A light, loamy, well-drained soil, with a moist atmosphere and frequent heavy showers, are conditions most favorable to its full development. These conditions are found in southern Luzon, Leyte, Cebu, Samar, Mindoro, Marinduque, Panay, Negros and Mindanao, especially in the district of Davao, where, it is said, the conditions are more favorable for abaca than in any other region. Albay province, in southern Luzon, famous for large exports of hemp, has an annual rainfall of nearly 120 inches, with over 200 rainy days. All the large hemp plantations in southern Luzon, called *"lates,"* are situated on the lower slopes of old volcanoes, the soil being chiefly volcanic ash and very fertile. The foothills and lower mountain slopes, covered with a medium growth of timber, which affords protection against high winds, are ideal locations for abaca.

Fig. 142. Abaca, or manila hemp (*Musa textilis*).

Fig. 143. Fruit of *Musa textilis*.

There are several varieties of abaca, distinguished by slight variations in their external characters; they differ, also, in the length, quantity and character of the fiber produced, and the comparative ease with which this fiber is extracted. *Samorong puti*, or white abaca, is one of the best varieties, yielding an abundance of fiber of excellent quality. Yellow abaca, *samorong pula*, is also a heavy producer, but the fiber is less valuable. *Isarog*, or mountain abaca, yields a very white fiber, but it is shorter than in the yellow and white varieties. *Quidit* is a slender variety, producing a long but delicate fiber. An exceedingly fine fiber, used by the natives, is extracted from *saba*, *butuhan* and *tindoc*, varieties of true bananas. Another variety, *samorong itom*, is classed with the best grown in Albay. Those kinds having the stem or trunk of nearly uniform diameter throughout are the best, the fiber being of more uniform length. (See Census of the Philippine Islands, VI, p. 168.)

In preparing the land for the establishment of an abaca plantation, all underbrush and trees not wanted for protection are cut away and burned when sufficiently dry. If practicable, the land is then plowed, thoroughly cleaned and staked off, the stakes being placed in rows nine feet apart each way, the stakes standing where the plants are to be set. If the plants are grown from seed, these are planted in small plots, and when three or four feet high are cut down to the ground, the bulb or crown is lifted, the lower third of the roots is cut off, and they are ready for planting in the permanent field. Seed-grown plants are ready for cutting in about five years.

The common practice in establishing a new plantation is to use suckers from old plants, or sections of old bulbs left after the old stems have been cut off. Suckers cost from $10 to $15 per thousand. These suckers are set out at the points indicated by the stakes, and then sweet-potatoes are planted to keep down the weeds and furnish food for the native laborers. Corn is sometimes grown for the same purpose, and this has the advantage of furnishing needed shade for the young abaca plants. When grown in this way, the abaca is ready for cutting in about two and one-half years. If conditions have been favorable, a dozen or more stalks will have sprung up from each root,

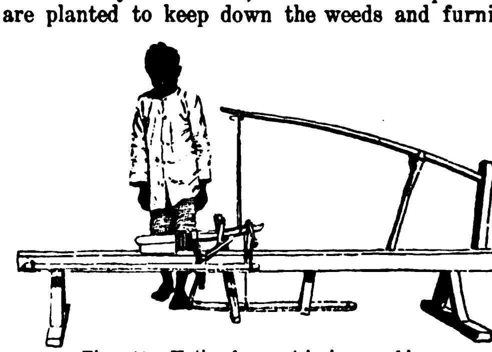


Fig. 144. Native hemp-stripping machine.

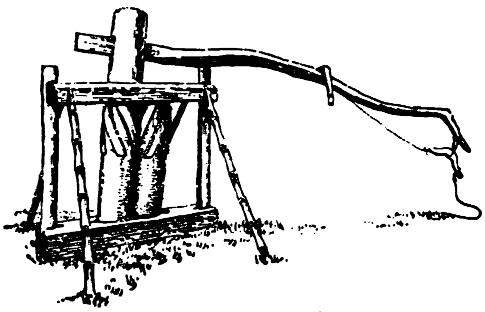


Fig. 145. Primitive sugar-cane mill, Philippines.

two or three of which will be mature enough for cutting at about the same time. The stalks are cut between the opening of the flowers and maturing of the fruit; if cut earlier or later, the fiber is of inferior quality.

The stem or trunk of the plant is from six inches to a foot in diameter and ten to fifteen feet long. It is made up of numerous thick, overlapping leaf-stalks surrounding a slender central axis, which is the true stem of the plant. The fiber that makes the "hemp" lies in the outer part of the leaf-stalks, and is obtained by drawing the strips, into which the stalks are divided, under the edge of a bolo, which removes the pulp. The bolo is held firmly with the edge, which is often finely serrated, resting against a block of wood, and the strips are drawn under this by hand until the fiber is sufficiently cleaned. Three men can clean 50 to 75 pounds of fiber per day. The fiber is dried, made up into skeins, and carried or shipped to points where it is pressed into bales, weighing about 275 pounds each, for export. There are eighty-three baling establishments in the archipelago, sixty-seven of which are operated by hand, five by steam and eleven by hydraulic power. A native machine for stripping hemp is shown in Fig. 144.

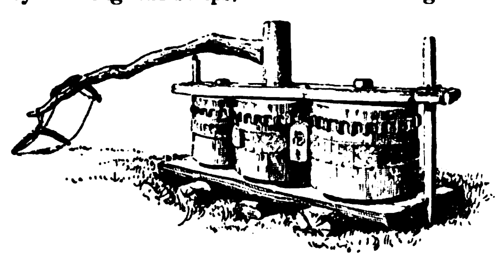


Fig. 146. A better type of mill for grinding sugar-cane.

The abaca industry is generally conducted under careless and wasteful management by most antiquated methods. By careful selection of land and the intelligent application of modern methods and machinery, there is every prospect of success. It is one of the most profitable branches of Philippine agriculture.

Sugar-cane.

For the year ending June, 1905, 250,542,682 pounds of sugar, valued at $4,977,026, were exported from the Philippines, nearly thirteen million pounds coming to the United States. The province of Negros Occidental furnishes three-fifths of all the sugar exported, and it is in this province that the industry is most highly developed, Pampanga, in Luzon, ranking second. There are about ten hundred sugar-mills whose output exceeds $500. Seventy-seven of these are run by water, 470 by hand or animal power, and 528 by steam. (Census of the Philippine Islands, VI.) There are many hundred smaller mills, all of most simple construction and easily made on the plantation. They consist of two or three rollers of wood or stone fixed upright in a wooden frame; to one of the rollers, which have interlocking cogs, a horizontal beam is attached. Figs. 145, 146, 147. In the grinding season, a carabao is harnessed to the outer end of the beam, and this slow-moving animal furnishes the power for turning the rollers, between which the cane is crushed, one stalk at a time, and the juice extracted. With few exceptions, the equipment of all the plantations is of the crudest character, the planters rarely being able to incur the great expense of improved modern appliances and machinery.

The methods of cutting and handling the cane are of the primitive nature, and consequently the results are far below what they should be, for probably there are no better sugar lands than exist in the Philippines nor a climate more congenial to the full development of the cane; especially is this true of the island of Negros.

There are several varieties of cane cultivated, which are recognized chiefly by their color. Purple cane is almost the only variety grown in the southern islands, while the white and the green are more common in Luzon. A red and a black variety with white rings at the joints are occasionally grown, the latter chiefly as a botanical curiosity. Early in 1903, a number of the improved Hawaiian varieties were introduced by the Insular Bureau of Agriculture, and their propagation is being extended.

The lands selected for the plantations are high and generally quite level, with rather moist, dark brown, loamy soil. After the soil has been thoroughly cleaned and well-worked by repeated plowings, the cane is planted, usually in November or December, and twelve or eighteen months later is ready to harvest. In most sections, the plantings have to be repeated every two or three years, but in the deep rich soils of Negros the cane lasts five to ten or even fifteen years without renewal.

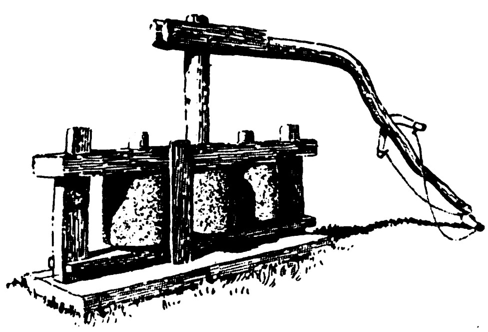


Fig. 147. Stone sugar-cane mill.

In Luzon, sugar is generally brought to market solidified in earthen cone-shaped vessels called *pilones*, each holding about one hundred pounds. In the southern islands, the granulated sugar is put into sacks, or *bayones*, made of the leaves of the buri palm reinforced by a covering of rattan. This is the style employed for packing all sugars designed for export. In 1893, sugar constituted 46.63 per cent of the value of all exports, since which time there has been a rapid decline,

Fig. 148. Coconut trees in the Philippines.

the percentage of value to the total exports in 1902 amounting to only 11.2. This has resulted from several causes,—unsettled political conditions, increased cost of labor, excessively high rates of interest on loans, and especially to the great loss of working animals from disease, some plantations having lost their entire stock.

Coconuts.

The coconut palm is common throughout the archipelago and in many places has been systematically cultivated, especially in the provinces of La Laguna and Tayabas on the island of Luzon. Bohol, Sámar, Leyte, Negros and the provinces of Surigao and Misamis in Mindanao, are especially rich coconut regions, the more southern districts producing the largest and finest nuts. No other plant in the islands yields so many useful products or enters more intimately into the domestic economy of the natives. The roots furnish a red dye; the trunk of the tree is used to support bridges and houses; the leaves make excellent thatch, and when stripped are woven into mats, baskets, and the like; sap drawn from the flower-stalk is "tuba," from which wine, vinegar, or, when distilled, brandy are made; the fibrous husk of the nuts is made into ropes or is used in calking boats; the hard shell is made into cups, ladles, spoons and other articles; the meat is used for food, either alone or mixed with rice; when ripe, the meat furnishes an oil supplying the chief illuminant of the natives everywhere in country and town, and it is also used in medicine, in cooking, and as a lubricant; the water, drawn fresh from the immature nuts, supplies a safe, cool and refreshing drink; the "milk" of the mature nuts is used in the preparation of sweetmeats and other native foods. Besides these, there are many minor uses more or less local in their application.

The making of tuba and the extraction of the oil are important industries, and it is the value of the latter product that places coconuts with the four great commercial products of the islands, being exceeded only by hemp and sugar. Comparatively, very few coconuts are exported, and up to the present time the shipments of oil have been insignificant. It is the dried meat of the nut called copra or coprax, that forms the article of commerce. The amount of copra exported during the year ending June, 1905, was over 82,000,000 pounds, valued at more than $2,000,000. All other coconut products exported amounted in value to less than $10,000. Coconut fiber, or coir, which in other coconut countries is an important source of revenue, is used only locally, in ways above mentioned, the greater part being thrown away or used for fuel in making copra.

Land for a coconut plantation is cleared as for other crops, the site selected being near the sea or along some watercourse. Holes are dug ten to fifteen inches deep in rows about nine yards apart each way, and into these holes the previously sprouted nuts are placed, the earth being pressed closely about them. In preparing for this planting, the nuts are selected a year in advance and placed in some shaded place on clean, mellow soil or, sometimes, they are tied in pairs and hung over bamboo poles. In two to four months germination takes place, and when the young shoots are two to three feet high the nuts are set out in the permanent plantation. It is customary to trim off the larger roots that have pushed from the germinating nut before planting them. The young plantations must be protected from the depredations of hogs and other animals and the ground kept comparatively clean. This is usually done, when the work is carried on systematically, by the cultivation of sweet-potatoes, upland rice, corn, peanuts or other small crops. Under favorable conditions, the trees will begin to bear in six or seven years and reach full maturity in about fifteen years from planting. A single tree will yield 80 to 100 nuts per year, although individual specimens may yield many more than this, sometimes running up to 250. It is a good plantation that averages 100 nuts per tree. The only implements used by the planter are a small bar, a rude spade, a short hooked knife attached to lengths of bamboo for cutting off the nuts, and the ubiquitous bolo. The nuts are gathered at intervals of three to four months, those which have ripened between each two periods being harvested.

There are many small plantations of 100 to 400 trees, and a single family can easily handle 500. The working of large plantations is based on this estimate, as on a plantation of 5,000 trees provision is made for ten tenants, who, with their families, do all the work. If the ground requires tillage, one carabao to each 1,000 trees is provided.

The copra is made on the place, the meat being dried either in the sun, which requires three to five days, or on gratings over a fire, the husks being used for fuel. The fire-dried copra is often more or less scorched and smoked and is inferior to the sun-dried, and brings fifty cents to one dollar less per picul in the markets. One thousand nuts will make about five hundred pounds of copra, which is valued at $2.50 to $3 per picul of 137.9 pounds. The cost of making 500 pounds of copra, including harvesting the nuts, is about $1.50. All the work is usually done on the share system, the tenant receiving one-third of the sales of the product.

One thousand nuts will yield about twenty gallons of oil, which is worth about fifty cents a gallon at the mill.

Tobacco.

Tobacco is grown throughout the archipelago, but it is nearly all consumed locally, excepting in the provinces of Isabela and Cagayan in northern Luzon. These two provinces produce the finest grades and supply practically all the tobacco exported. The value of this export for the year ending June, 1904, was $2,010,587, and for the period ending June, 1905, it was $1,999,193.

The lowlands bordering the river, enriched by annual overflows, are deemed the best for tobacco, and command the highest price. The uplands yield an excellent product for two or three seasons, but their fertility is quickly exhausted and, as the Filipino uses no fertilizers, they are soon abandoned.

The same rudely constructed farming tools are used in the growing of tobacco as for rice and other crops. The seed-beds are first prepared sufficiently large to contain about one-half more plants than required for the plantation, and the seed, mixed with ashes or dry sand, is sown in July or August, or, for the lowlands, in September or October. In about two months the seedlings are ready for transplanting to the fields which, during this time, have been prepared by repeated plowings. One man with a carabao and native plow can break up one acre in five days.

There are several varieties of tobacco in the islands, those most widely grown in the northern provinces being the Habana or Isabela and the Vizcaya. These grow to the height of five to six feet, with rather narrow leaves a yard or more in length. Early in 1903, the Insular Bureau of Agriculture made an experiment in growing Sumatra tobacco at the station in Manila. The plants were set out February 14 and the final cutting was made July 7. The rate of yield per acre was 1,470 pounds. The leaves were very thin, elastic, light-colored, with a fine silky luster, having every appearance of the finest wrappers.

Fig. 149. Shed for drying coconuts.

The tobacco industry is considered the most remunerative in the islands. With intelligent direction and a little more energy on the part of the native planter, the tobacco crop might be both increased and greatly improved, while the use of fertilizers would make possible a great increase in the present area under cultivation.

Secondary fiber plants.

Cotton of the long staple variety was introduced into the islands by the Spaniards many years ago, and formerly was grown extensively in Ilocos Norte and neighboring provinces. Its cultivation is still practiced to a limited extent, the Ilocano provinces producing about 73 per cent of the quantity raised. There is some cotton grown in La Union province on the western coast and in Batangas in southern Luzon, but their combined area in this crop is only about one thousand acres. The system of cultivation and methods of handling the product are of the simplest and most primitive character. The Insular Bureau of Agriculture is directing attention to the possibilities in cotton-culture under improved methods and increase of area. All the cotton grown is used by the grower or sold to the cotton-mill in Manila.

A variety of agave, probably *Agave vivipara*, was introduced into the islands many years ago, and has been widely propagated under the name of maguey. It is grown in commercial quantities in the northwestern provinces of Luzon, the product being shipped to Manila and exported to China, Japan and Europe. The value of the exports for the year ending June, 1905, was nearly $200,000. Maguey fiber is nearly identical with sisal, and is used for similar purposes. The finer and more delicate grades are used by the natives for making a cloth called *nipis*.

The fiber of maguey is extracted almost entirely by maceration, a slow, disagreeable and wasteful process. From the fact that maguey can be grown in districts entirely unsuited to abaca, and on soils which otherwise would be wholly unproductive, the extension of its cultivation is being urged by the Insular Bureau of Agriculture, and already much interest is being awakened in the subject. Efficient machines have already been invented for extracting the fiber, and with the introduction of these the maguey industry will doubtless become one of great importance and yield large returns to the planter.

The pineapple, introduced into the islands many years ago, is now very widely distributed, being grown chiefly as a fiber plant. The demand for the fruit in the Manila markets is supplied from the neighboring provinces. In southern Luzon, Panay, Negros and Cebu, the raising of pineapples for the fiber product is a minor, but important industry. The fiber is obtained by scraping away the pulp of the leaf with a bit of glass or small iron or sharpened piece of bamboo held in the hand. It is estimated that a ton of leaves will yield, by this method, about sixty pounds of clean fiber, which is comparatively strong and remarkably fine. It is woven by the natives into a cloth of extreme lightness and delicacy, called *piña*, a termed applied also to the fiber itself. It is used for women's garments and for handkerchiefs, collars, scarfs and other ornamental articles of dress, the pieces often being embroidered very elaborately and handsomely. *Jusi*, another fine native fabric, is woven from piña mixed with abaca and silk.

Various other important crops.

Indian corn was introduced into the Philippines by the Spaniards and is now widely grown. It constitutes the staple article of food in Cagayan and Isabela provinces, and is almost equally important as a domestic product in the islands of Cebu and Negros. The total product for the archipelago, as given by the Philippine census, is nearly four million bushels, an exceedingly large quantity considering the indifferent cultivation received. Two and sometimes three crops per year are raised from the same land. The tobacco lands in Cagayan and Isabela are often devoted to corn during the rainy season. The grain is usually eaten from the ears, after partial roasting ; in a few localities the corn is ground into a coarse meal and then boiled in water without salt. Corn is also fed to poultry, and the stover to carabaos. An alcoholic beverage, called *pangasi*, is made from the grain in the southern islands.

Sweet-potatoes, or *camotes*, of which there are several varieties, are eaten either boiled or roasted, or are made into preserves or sweetmeats. Next to rice, camotes are the most important food product and are grown everywhere throughout the islands, especially in the mountain districts. They form the chief product of the mountainous island of Sámar, where the crop is estimated to be about fifty million pounds. When once planted they require but little attention. The vines spread in all directions, taking root and forming tubers which may be dug as wanted throughout the year, so continuing to grow until the land is wanted for some other crop.

Cacao is largely grown. The islands yielding the largest amount of cacao at the present time are Luzon, Cebu, Bohol, Mindanao and Leyte, but the tree is grown more or less extensively throughout the archipelago, there being few places where one or more trees in yards about dwellings may not be found, supplying the immediate wants of the natives. Comparatively little effort has been made to establish large plantations. Cacao (yielding the manufactured product known as cocoa) of the finest quality is produced in Mindanao, and the systematic cultivation of the tree in the fertile districts of Davao and Surigao would certainly be very profitable. At present, all the product is consumed in the islands in the manufacture of chocolate.

Coffee is grown to some extent in many of the provinces. In 1887 it constituted 8.29 per cent of the value of all exports, and the shipments in 1889 were valued at over $1,800,000. The exports of 1905 amounted to less than $3,000. The ravages of insects and disease have practically destroyed the plantations that formerly yielded such abundant crops and almost princely revenues. Efforts are being made to revive the industry by the establishment of plantations in new districts, especially in the provinces of Benguet and Lepanto Bontoc in Luzon, and in the provinces of Mindanao, with most promising results. [For the beginning of coffee-culture in the Philippines and methods of cultivation, see Census of the Philippines, Vol. IV.]

The blossoms of ylang-ylang or ilang-ilang tree (*Cananga odorata*) yield an essential oil, *Oleum anonæ*, of great value in perfumery. The collection of the flowers affords a small revenue to a large number of the poor people. The tree is cultivated to some extent, but it also grows wild, and the flowers from the mountain districts are richer in oil than those from the lowlands. The oil is distilled in Manila. The value of the export for the year ending June, 1905, was $100,349. [For illustration of ylang-ylang, see Fig. 1754, Cyclopedia of American Horticulture.]

Pasture and forage.

There are thousands of acres of open country in northern Luzon covered with wild grasses of fine quality, valuable alike for hay or pasture. Good grazing lands are to be found on most of the islands, sufficient for supporting large herds of horses and cattle. The principal grasses of these meadows and grazing lands belong to the tribe Andropogoneæ. Species of panicum and eragrostis also occur more or less abundantly. In cultivated lands Bermuda grass prevails, while near the coast Korean lawn grass predominates. Nowhere is there any attempt made to make hay, the daily needs of the larger cities and towns being supplied with freshly cut grass brought into the markets each morning from outlying fields. Manila is supplied almost entirely with a grass (*Homalocenchrus hex-*

andrus) extensively grown in the surrounding country. It is planted in the mud in paddies, the cultivation being practically the same as for lowland rice. Locally this grass is known as "zacate." (Fig. 139.) It is cut with a small sickle-like knife, and tied into small bundles each about the size that can be grasped by the hand. One hundred of these little bundles retail for fifty cents. The zacate lands about Manila are rather extensive, and in average seasons yield their owners large incomes.

Rice straw, unhulled rice or *palay*, and corn are all used for horse and cattle food, and, to a very limited extent, sorghum also. The Insular Bureau of Agriculture, in 1903, demonstrated the possibility of successfully growing teosinte, varieties of sorghum, cowpeas and velvet-beans as forage crops. These can easily be made available anywhere in the islands, and where grown there need be no further necessity for American or Australian hay, that is now purchased at great expense.

American vegetables.

Since American occupation of the islands, efforts have been made to introduce American vegetables, especially by the Insular Bureau of Agriculture, through distributions of American-grown seed to all the islands and by trials at the experiment stations of the Bureau. The results obtained by the natives have rarely been successful, chiefly through indifference or lack of knowledge of the necessary requirements for success in cultivation. Such vegetables as tomatoes, onions, lettuce, radishes, beans, eggplants, okra, peppers, squashes and cucumbers may be grown anywhere with proper care. Most of them are grown by the natives, but they are inferior both in size and quality. In the mountain regions of Benguet and the highlands of Mindanao, all products of the warmer temperate latitudes thrive and yield abundant crops. Ants are a great pest to the market-gardener, devouring or carrying away small seeds as soon as planted. It is necessary in some cases to start the seeds in boxes placed where the ants cannot reach them, and later transplant to the open ground.

Domestic animals.

The domestic animals are the carabao, or water-buffalo, neat cattle from India and Australia, horses of the pony size, swine, chickens, ducks, geese, and a few inferior sheep and goats. There are also a few Australian, Chinese and American horses and mules.

The most important animal and the most essential to the Philippine farmer is the carabao. This animal is about the size of the American ox, slow and awkward in its movements, but of great strength; it is very dark gray or nearly black, thinly hairy, with a comparatively small head and large, curved horns. The flesh is not very palatable to the American taste; the hides and horns are of much commercial value, and, besides supplying a large local demand, are exported to China and the British East Indies. The value of this export for the year ending June, 1905, was $184,962. Carabao were in the islands when the Spaniards took possession, and the native farmer is practically helpless without them. It is very largely due to the great losses sustained by the Filipinos through the death of these useful animals by rinderpest in recent years, that the rice-crop has been so short and other farming interests stagnated. The estimated loss from disease in 1902 was 600,000, or a little over 43 per cent of the total number in the islands. The mortality in some districts reached as high as 70 per cent. Such losses have naturally had a most depressing effect on all farm industries. The carabao is amphibious in its habits to the extent that it must spend a part of each day in the water. A few hours' work in the sun without a bath is often fatal. During the heat of the day they seek shallow water, in which they lie down with only their heads appearing above the surface. It is their habit to dip the head under the water and raise it up suddenly to throw water over the back if this is not covered. There are wild carabao on some of the islands. Such animals are often vicious and dangerous to meet. The average price of good carabao steers is about $50.

Indian cattle are bred in large numbers in some of the provinces and islands, and are used to some extent for draft and work animals, but are chiefly valued for meat. In Dagupan and a few other provincial towns, the small Indian bulls are used not only for draft but also for driving. They make excellent carriage animals, and will cover long distances at an easy trotting gait. The general average price of India cattle is $20 to $25.

The native horse is a small, stockily built, but well-shaped animal. He rarely weighs six hundred pounds, usually much less. When well-kept, the stallions are full of spirit and often very fast, making excellent race-horses for short distances. The best ponies are raised in the province of Batangas, where there were some 15,000 in 1903. The losses from surra and other diseases during 1902 have been placed at 33 per cent of the whole number; in some provinces the losses amounted to over 90 per cent. This was the case in Bohol, Tarlac and Ambos Camarines. The native horses are valued at $20 to $25. Well-matched spans and the finer carriage and racing animals are much higher-priced than this. There are less than 300 mules in the islands, exclusive of those belonging to the War Department, and less than a thousand American horses. Practically no efforts have been made toward the general improvement of the native horses by selection and breeding.

It is estimated that there are over a million hogs in the islands. They are poor in breed and receive little attention from their owners, being allowed to run at will. They are excellent scavengers but rarely get fat; their general appearance is much like that of the "razorbacks" of the southern United States.

Chickens are found everywhere, few families being so poor as not to be able to have a rooster, of the game variety, and a few hens. Cock-fighting is the universal sport, and the breeding of game-cocks is of more importance to the native than raising poultry for food or for the eggs. The estimates based on the returns of the Philippine census place the total number of chickens at nearly five and one-half millions. From the same returns, made in 1903, there were in round numbers, 78,000 ducks, 9,000 turkeys and 6,000 geese. In the vicinity of Manila the raising of ducks is an important industry. The eggs are hatched in lots of 1,000, by being placed between bags of heated rice-husks. The male ducks are sold in the Manila markets at an average price of forty to fifty cents each.

The outlook for agriculture in the Philippines.

The principal industries of the Philippines are agricultural, and whatever of value the islands may have in the future lies in the development of these industries. By intelligent direction and the introduction of modern machinery and methods in the growing and handling of crops, the islands may be made to yield every tropical product required by civilized peoples, and in quantities sufficient not only to supply the vast demands of the United States for such products, but also to command a share in the other great markets of the world.

The four great staples, hemp, sugar, copra and tobacco, now constitute about 90 per cent of the value of all the insular exports. Hemp, the one peculiarly Philippine product, alone yields over 65 per cent of the total amount, yet there are many thousands of acres of this product annually going to waste, because of lack of suitable means for extracting the fiber, and there are yet many other thousands of acres of most excellent but unoccupied hemp lands awaiting the energy and capital necessary to cover them with the richest product of the islands. Hemp plantations require no great amount of skill or experience in their establishment; the plant has no insect or fungous enemies, and a market for the product is always assured. The most prosperous districts in the islands today are the great hemp-growing regions in southern Luzon and the Visayan islands. What is said here in regard to hemp production applies with almost equal force to copra, a coconut product, which for the year ending June, 1905, held third place among the exports, sugar standing second and hemp first. Like hemp, the coconut is a native product, growing wild throughout the archipelago. Comparatively little effort is made toward its systematic cultivation, and such cultivations as are made are, for the most part, of very limited extent. Coconuts are less restricted than hemp by soil and climatic conditions, and while they do not yield so quick returns, the care involved in the coconut industry is far less laborious and exacting, and the profits are as certain in the one case as in the other. The copra industry is practically in its infancy, at least so far as regards its present extent, and as to the other commercially important product of the nut, the coconut fiber or coir, it remains wholly undeveloped. The possible production of sisal hemp (maguey) in the islands is almost limitless, while the opportunities for establishing extensive coffee plantations are peculiarly tempting. The world's demand for chocolate is now very great and constantly increasing, and there is probably no other region in the world where cacao orchards are so certain of yielding as abundant harvests of the choicest product. The spices, cinnamon, nutmeg, and the like, are natural products of the islands and require only a little attention to make them yield a goodly revenue. All conditions necessary for the successful propagation of the vanilla plant are found here. Lemons and oranges grow wild on many of the islands; and so do rubber-plants, and plants producing gutta. The field is a broad and inviting one. The islands are tropical, and the products that will always succeed the best on them are those everywhere recognized as belonging to tropical countries. It must also be borne in mind that the agricultural organization and methods must be fully adapted to tropical conditions, for the practices of necessity differ in many particulars from the methods of temperate latitudes.

Those who desire statistical and other information respecting the agriculture of the Philippines, should consult the Census of the Philippine Islands, Washington, published in 1905. The statistics were taken in 1903.

Work of agricultural education organization in the Philippines.

With the object of promoting the interests of agriculture and improving the methods of cultivating the soil, the Insular Bureau of Agriculture has done much by introducing the latest and most improved farming implements and machinery and the conducting of demonstration work at the various experiment stations in Manila and elsewhere. The first specific case of the demonstration of the use of American tools and methods was made by the Bureau at Batangas, in coöperation with the War Department through General J. F. Bell, October 20, 1902. All the presidentes in the province were invited to attend, and there was a large assemblage to witness the work and inspect the appliances and machinery; much satisfaction was expressed at the results.

Similar work has been conducted by some of the provincial supervisors, and in 1903 the Bureau of Education began advancing the work by introducing simple agricultural teaching into the public schools, and, when circumstances would permit, establishing gardens about the schoolhouses where practical work in various lines could be conducted, in harmony with modern educational methods.

The Insular Bureau of Agriculture has accomplished much in the way of diffusing agricultural information through its annual reports, bulletins and other publications. For the most part, these publications have been issued in both English and Spanish, and in one instance in Ilocano.

The publications of the Bureau of Agriculture are issued in two series: The first, under the general title of farmers' bulletins, containing information compiled from various sources relative to agricultural matters, prepared in a popular style, for the purpose of diffusing agricultural information; the second series is more technical.

PART II

THE PROJECTING OF A FARM

Advice on the considerations involved in the choosing and organizing of a farm should precede instruction on the methods of growing crops and live-stock. These considerations are of many kinds, but inasmuch as they are introductory they may be assembled in one fascicle. The project must be analyzed: the farm must be chosen, its general plan or scheme determined, the required capital discussed, machinery considered, buildings and fences described, sanitation and water-supplies given attention, and finally the artistic setting of the homestead must be regarded.

CHAPTER III

ON BUYING A FARM AND BECOMING A FARMER

SELECTING A FARM requires more care than the choosing of almost any other property, because there are so many considerations that go to make up its value. The experienced farmer is aware of this fact, and he buys with caution and seldom makes a serious mistake. Therefore, the present chapter of advice is not for him. The city person, however, is very likely to make a mistake; and it is easy to give advice to one who has no exact knowledge of the subject. This chapter is wholly for the novice who wants a farm. Having read all the previous pages, with their bigness and their prophecy, the novice will want to buy at once, and he will ask the Editor to tell him where to settle; the Editor will consider his case forthwith, and then proceed.

The first question for the enquirer to determine is whether he really wants a farm. If he thinks that he does, he should ask himself soberly why he does. Perhaps he has read florid accounts of the money that can be made from a farm: he must not be misled; he should determine whether the writer spoke from fact or from fancy, whether he or his associates have land to sell, whether the profits were accidental for one or two years, whether the case is isolated or is typical of a region or an industry. Having analyzed the desire and traced it to its source, the enquirer may require no advice from this chapter.

Perhaps the person loves the country. This is laudable, but it constitutes no reason of itself for buying a farm. The countryman may like the city, but he does not buy a flat for that reason. Mere love of the country, good and essential as far as it goes, will not make a man a farmer. Persons who desire to satisfy merely their longing for the country would better take vacations there or buy a country home.

The reasons for buying a farm are two: the desire to be a farmer; the conviction that a farm may be a good investment. Many other reasons may contribute, but these dominate.

Whether a person will make a farm pay will depend on whether he is a good farmer and has good business instincts. There is no more reason to expect that a person who has no practical knowledge of farming will make a good living on a farm, than to expect that one who has no knowledge of the profession can make a success of engineering. As compared with many other businesses, high-class farming is complex and the factors are not under control. There are persons who make a success of farming without previous experience, but there are many more who make a failure; and those who make a success, learn the business as they proceed and do not jump to fulfilment at a single bound. Mere reading knowledge will not make a good farmer. Usually the novitiate who has been reared in other environments is an eager reader, and he is likely to acquire a miscellaneous lot of facts that will have little relation to each other or to practice until they are jolted down by experience.

In looking for a farm, the enquirer should consider the question primarily from a business point of view. He should know what are the "points" of a good farm. It is well to make a list of the points, to study the place with reference to them, and to score it under each, as one would score a horse or a cow. The points or attributes are of two classes : those that are internal, or part of the farm itself ; and those that are external, or have to do with geographical location, neighborhood, and the like. Some of the points may be mentioned :

Internal

Lay of the land, or topography,
Size of the farm,
Shape of the farm,
Kind of soil,
Condition of soil as regards fertility and physical properties,
Drainage,
Water-supply,
State of cultivation,
Crops now standing, and their condition,
Woodland,
Character of fields and of fences,
Buildings and other improvements,
Kind of farming to which place is adapted.

External

Climate,
Healthfulness,
Neighborhood,
Distance from town or railway station,
Shipping facilities,
Means of communication,
Labor supply,
Markets in which to buy and sell,
School and church privileges,
Character of the farming in the community,
Rural organizations,
Likelihood of increase or decrease in value.

If the enquirer wants a farm for profit, he must take care not to be deceived by the looks of the place or by the attractiveness of the view. If the buildings are unusually good, he should determine whether they were built from the proceeds of the farm, or from other proceeds; if built by the farm, either the land or the management of it is excellent, usually both. Slattern fences and buildings, poorly clothed and poorly fed occupants, raise a suspicion as to the character of the land.

More attention should be given to the soil than to any other single feature of the farm itself. The real character of the soil may be determined by a careful examination of it and by the kind and condition of crops that are growing on it. Usually a heavy, smooth turf, if the place is in the North, thrifty-looking trees, sleek and plump stock, indicate good soil. Certain kinds of weeds and other plants indicate the character and condition of the soil: clover, timothy, pig-weeds, most strong annual weeds, suggest a good soil; mullein, daisy, narrow-leaved plantain, wild carrot, indicate either a poor soil or one that has been badly handled.

A careful laboratory analysis of the soil will be useful, particularly when one is in doubt or when one wishes to grow special series of crops. The analysis should be physical as well as chemical: of the two, the examination as to physical characteristics and condition may be the more important. The final proof of the capabilities of a soil, however, is what will grow on it; and this is to be determined by growing the crops rather than by laboratory tests. The laboratory examination will aid in arriving at a judgment, and it often gives most useful suggestions as to practice.

The old and persistent idea that a chemical analysis will tell just what a soil is worth, what will grow on it, and what fertilizer it should receive, is erroneous: this notion is a heritage from the recipe epoch of agricultural enquiry. On this point, a chemist (Professor G. W. Cavanaugh) may be quoted: "An analysis of a soil consists in finding the amounts of nitrogen, phosphoric acid, potash, lime, magnesia and humus that it contains. It may be carried farther and the amounts of other constituents determined. These materials, except the humus, are extracted from the soil by strong acids. The action of these acids is many times stronger than is ever brought to bear by plants on the soil in its normal condition in the field. It is, therefore, impossible at present to draw any certain conclusions from the results of such an analysis that are applicable to field conditions, since the acids used in the laboratory dissolve out much more of the plant-food in the soil than is ever in solution in normal soil water. If, however, an analysis shows only a very small amount of nitrogen, then one can certainly conclude that the soil is deficient in this element and would probably be benefited by its application. A soil deficient in nitrogen is constantly showing its condition in the growth of the plants on it. Short growth of straw and vine, failure to develop a full, dark green color in the foliage, and the growth of sorrel and ox-eye daisy, all tell as accurately as the chemist, with all his skill, that the soil lacks nitrogen. It is the same with the other constituents. It is only when a soil is extremely deficient in certain plant-foods that an analysis of it shows the cause of the trouble. We must remember that the great majority of all soils, good and poor agriculturally, differ only within narrow limits as to their composition. Every soil that yields well does not contain more plant-food than one that yields poorly: on the other hand, many soils that give poor yields are often rich in plant-food. The chemical composition is not always the deciding factor in fertility. As a matter of fact, it is rarely the deciding factor. Equally important for the plant are heat, air, light, good tilth and moisture. The writer once analyzed a soil that showed high amounts of plant-food, and yet the yields were very low. A good sytem of tile-drains was put in this field, and three years later the crops were very large. The draining produced no change in the composition of that soil, but it brought success. There is a more or less widespread notion that, if one knew the relative amounts of plant-food in a soil, a deficiency of one might be remedied by adding it in some fertilizer. This may be true in the case of nitrogen, but that can be determined by the growth of crops, as pointed out above. In most cases the failure to grow good crops is due to some of the other factors of plant-growth not being right, and not to a mere lack of plant-food."

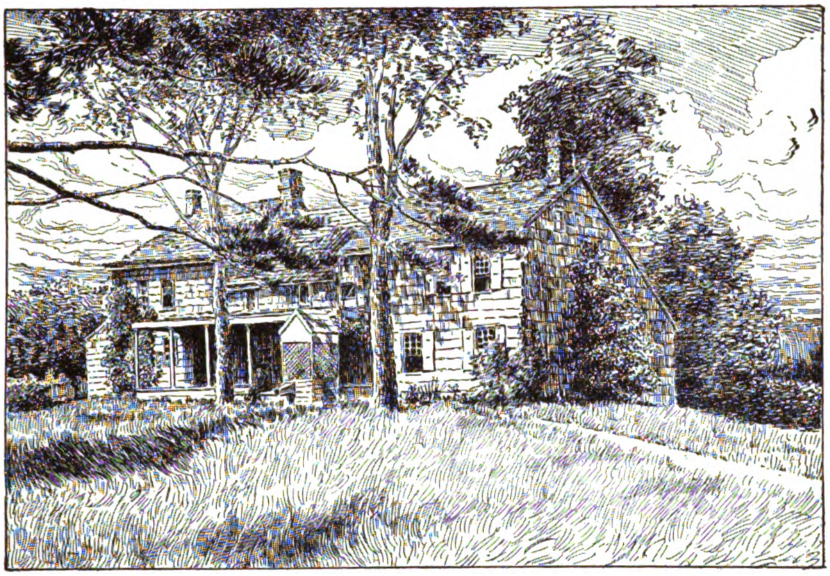


Fig. 150. A type of farmhouse that is well worth preserving, if the construction is still sound.—This particular building is an historic structure on Long Island, New York, built by the first settlers.

The beginner is likely to be attracted by the so-called "abandoned" farms, in much the same way, no doubt, that one is attracted by a bargain counter at a store. An abandoned farm may or may not be a bargain; the presumption is that it is not a bargain, for if it were of first-class value the occupiers probably would not have left it. The intending purchaser should determine why the farm is abandoned before he allows himself to be tempted. Cheap farms, like cheap goods, are likely to prove unsatisfactory and even dear in the end. It is a common notion that one may well buy a "worn-out" farm, and then bring it up to a high state of fertility. In most cases, such land can be renovated and made productive, but the process requires skill, takes time, and usually costs more than to buy good land in the beginning. Of course everything depends on how badly the land is worn and what the facilities are for recuperating it. The new farmer usually has enough other problems without beginning with a serious handicap in the land itself.

Where? There is no one place that is best for a farm. The part of the earth is usually more important from the personal standpoint than from the agricultural standpoint. All the preceding pages testify to the fact that agriculture thrives practically everywhere. Some crops demand certain climatic conditions, and of course these conditions must be met; there are great geographical regions in which certain kinds of husbandry reach their highest state; but there still remains the widest choice as to region, and one cannot give general advice. For certain kinds of agriculture, the old East is better than even the agricultural West. Some persons long merely for a change of climate and scene: this may be commendable, but it is not often required by the necessities of farming. Skill in farming will succeed anywhere, if it is combined with good business ability. Persons who fail in one place are likely also to fail in another. Climate and geography cannot take the place of personal ability, not even if the climate is the most propitious on the earth.

The novice must be on his guard as to literature. Many books and magazine articles contain just enough truth to make them dangerous. The safe book is more than likely to be somewhat dry, or at least not to fire the enthusiasm to white heat. It is a good rule to beware of any book or article that makes farming very easy, and that does not state the cautions and warn of the disabilities.

In the choice of crops, it is always safe for the beginner to avoid all high-class and narrow specialties. In certain hands, and under ideal or unusual conditions now and then, these specialties turn handsome profits, but this does not necessarily commend them. Mushrooms, Angora goats, ginseng and all fancy crops and breeds should be taken up with great caution. It is the shortcoming of the person who has read much and has practiced little to pick out isolated crops or products; but the good farmer is the one who works his practices into a system. This system should be such as to conserve or even increase the productiveness of the soil, to economize labor and other expenditure, and to furnish a sustained effort, and to allow some leisure.

It is not the purpose of this editorial to make it difficult for the beginner to choose a farm. The Editor has no desire to discourage any one from going on the land. There are great possibilities in agriculture, and the kinds of agriculture are so many that almost any person can find a type of business to his liking. But it is desired to let the learner know that farming is a serious business (if it were not, there would be no need of a Cyclopedia devoted to it), and to set some of the problems before him. The beginner is sure to meet these problems, and he would better meet some of them before he buys his farm. Usually he should not rely on his own judgment alone. It is likely to pay, in the long run, to seek the advice of an experienced and cautious man. The kind of advice that such a person would be likely to give is indicated in the three articles that follow.

GENERAL ADVICE TO THE CITY MAN WHO WOULD BUY A FARM

By *George T. Powell*

For many years the city man has been attempting to manage land. For a few months he hopes to secure from it some degree of pleasure, a larger measure of health, and, in some instances, a margin of money profits. Unfortunately, however, instead of managing, in too many instances he is managed. Through some land-agent he has probably covered the farm with dollars in the fictitious price he has paid for it, and everything he has done by way of building and improvements has been in a most expensive, even extravagant way, until he finds his country place to be a costly burden.

In the choice of a farm by a city purchaser, when personal knowledge of farms is limited, the services and advice of some competent authority should be sought, to whom may be given the main points that are desired in the proposed farm. This would include the section or locality that is preferred; the size of the farm; the general policy that is to be carried out in building; whether extensive, formal landscape work, requiring road-building, construction of artificial lakes or ponds, forest- and ornamental-tree planting, or the planting of orchards of fruit trees is to be done; also, whether a dairy is to be kept on the farm; whether horses, sheep, pigs and poultry are to be included; and to what extent agriculture as a business is to be made a feature of the plans of the farm. The purchaser should consult this expert in the same spirit in which he would consult an engineer or a lawyer in case he needed engineering or legal advice.

Fig. 151. A common type of run-down farmstead. Such buildings are likely to attract the city man who thinks that a cheap place may be readily reconstructed into a desirable habitation, but they usually prove to be the most expensive in the end and are incapable of being made really satisfactory.

With the policy defined, if a particular farm is under consideration, it should be carefully examined by the expert as to the character and condition of the soil, the suitability of the place for the purposes desired, the extent and quality of the water-supply, the best location for the buildings, the natural landscape effects of which advantage may be taken; and all of these considerations should be embodied in a definite report that will give a comprehensive idea of the advantages and disadvantages of the farm. In addition to the farm itself, the neighborhood should be considered, its social advantages, roads, telephone and mail facilities, all of which are now essential to the city man who plans to spend an increasing part of his time on a farm.

If the purchaser plans to buy a farm for the purpose of developing certain lines of agriculture, and to give to it his best thought and business energies, the relation of the farm to transportation and to markets becomes highly important, as also the labor facilities that may be at command.

In the construction of buildings, the expert should make a study of the natural materials in stone, sand and gravel that may be on the place, and the extent to which these may be utilized. Information should be secured as to the kind and amount of machinery that will be necessary, the varieties of fruits best adapted to the soil and location; if orchards are desired, the cost of trees and of planting them, and the capital required to maintain them until they become productive. The purchaser should secure information on the cost of labor, the purchase and cost of supplies, and an approximate estimate of the capital necessary to conduct the business successfully. Were this information first obtained, there would be much less

Plate VIII. Farm lands in New England. Guernsey herd of Arthur H. Sagendorph, Spencer, Massachusetts

disappointment, and far more satisfaction, in the experience of buying a farm and developing a country home. The city man has little knowledge of the land, even though he may have been born on a farm. He probably left it when a boy, and conditions and methods are so changed that his early knowledge is of little service to him.

After obtaining the best information regarding the character and value of the land, he should secure a wide-awake and educated manager. Preferably, this should be a young man who has lived on a farm and has secured some knowledge of its practical management, supplemented by scientific knowledge gained from a course of study in an agricultural college. The services of such a man are invaluable, and they cannot be obtained at the ordinary value of farm laborers. One of the most costly mistakes a city man can make in conducting a farm of the management of which he has little knowledge, is in employing a manager who has no more knowledge of the business than himself. It is astonishing that good business men, who pay high salaries for competent managers in their city business, will still cling to the old scale of wages when hiring a manager for a farm, forgetting that as much skill is required for the farm managership as for any other, and that the years of preparation at college entail expenditure of effort and money. Moreover, the owner must see to it that this intelligent farm manager is accorded the social position that his training and ambition deserve.

Numerous illustrations could be given of the value of securing skilled services on the farm, and particularly on the suburban farm. Within an hour's ride of New York city is a farm of three hundred acres, owned by a prominent business man. He is fond of short-horn cattle and is interested in pastures, hay and corn. By seeking the best information to be secured and applying it, through the selection of well-bred seed-corn and giving higher tillage, he increased the yield of corn from sixty to seventy-four bushels per acre the first year, and in a season not favorable for the growth of corn. The yield of hay was increased from one and one-half tons to four and one-half tons per acre, while greatly improved pastures were made through better preparation of the soil and more liberal fertilizing and seeding.

On another suburban farm, by employing a poultryman who had taken a course at an agricultural college, a profit of 40 per cent on the investment in the poultry department was secured, while on the same farm the superintendent was allowing the liquid manure from a pit to be carried off in an eight-inch drain, not only to be lost but to contaminate the drinking-water of a herd of valuable cows.

On still another farm, an hour's ride from New York city, is a farmer with only a common-school education. He was having a hard struggle with his farm, and when confronted with the prospect of his children leaving the farm to try to better their condition in the city, he called to his aid agricultural expert counsel. His farm was examined, and the soil being especially adapted to the growing of peaches and strawberries, the system was changed and orchards planted, which have since made him financially independent. In this case, special study was given to the demands of a good home market. Varieties of the finest flavors were planted, and they were marketed when nearly ripened and at their highest excellence. The second crop of these berries cancelled a mortgage, and the third gave a comfortable bank surplus after paying the farm expenses.

Fig. 152. Cheap farm buildings that may be worth buying.

The gentleman farmer is frequently ridiculed by the man that makes a living by farming, because of the belief that all crops grown on such farms are produced at a greater expense than their cost in the market. That such belief is far from correct in many cases, there is no doubt. The following is given to support this statement: A certain place had a live-stock superintendent, who had a poultryman under him at $45 per month, or $540 per year. Supplies averaged $30 per month, or $360 per year, making the total expense $900 per year. The earnings were, for ducks and duck eggs $230, squabs $390, hen eggs $300, broilers $35, roasters $90, capons $58, making the total earnings $1,103, against $900 expense, leaving a profit of $203. In this estimate nothing is said of old stock sold, which paid for the raising of the breeding-stock for the following year. The manure was given to the farm in partial return for roots, hay and straw. This was the first year of systematized work. The poultryman could take care of four times the amount of stock he had, and therefore he cared for thirty ewes and drove a delivery wagon once a day to and from the station three miles from the farm.

Agriculture is a business that produces much wealth, and in its successful conduct calls for a broad and most diversified knowledge. As this fact becomes better understood, educated service will be demanded on the farm, and suburban farm life will be ideal in the many advantages it will then have and the high order of pleasure it will yield.

ADVICE TO THE CITY MAN WHO WOULD UNDERTAKE SMALL FARMING

By *C. C. Hulsart*

There are thousands of persons who are tired of the noise and hurry of the city, and who would like to escape to a small farm. Of course, one cannot safely recommend the small farm to every discontented city person. There are some city men and women who can make a comfortable living from a farm, but many more who cannot. It is disheartening to consider the money that is wasted by well-intentioned men from the large cities, who think that all they need to do is to find a good-looking farm with handsome buildings in a desirable location, hire a man, and then leave the enterprise to itself.

Too often the fact is overlooked that successful farming demands as intimate knowledge of the business as does any other pursuit. The intending farmer must have some knowledge of farm tools and their use. He must be familiar with the crops to be grown, and the adaptation of them to the soil and climate. The failure to grow crops that are adapted to the soils of the particular farm is a common source of disappointment. It is of first importance that the market be considered, as this will determine, in large measure, the kind of farming. If the products are to go to a home market, more diversified cropping will be practiced, the individual crop acreages be reduced, and more intensive methods practiced. If the person is intending to handle stock, a general knowledge of the requirements of the kinds to be kept is equally essential. Adaptation of the kind of farming to the local and special conditions is one of the prime requisites to success.

Fig. 153. Evidences of a good farm. The pasture is good, the sheep plump, and the field is tidy and well kept.

One of the most common mistakes made by city men going into farming is starting on a too large scale before the business has been learned. The only safe way for the novice is to begin in a small way and enlarge as he becomes familiar with the business. It will usually be advisable to rent a farm for the first few years with the prospect of buying. This will allow the prospective farmer to begin at a minimum of expense; then, after a short trial, he will be more competent to judge whether or not he wishes to continue; if not, he can draw out without having a farm on his hands which might have to be sold at a sacrifice. The writer moved from the city nearly twenty years ago, when he did not have capital enough to buy a farm. He rented, and in time was able to buy. The business, although entailing hard work at times, is financially successful and is most agreeable and independent. The area now comprises thirty acres, with ten acres more that is rented. The entire establishment has cost about $8,000. The net profits will average 20 per cent on the investment.

It will be well to begin with ten to twenty acres, according to the kind of farming to be practiced. Ten acres is sufficient at the start if market-garden crops are to be grown. The new farmer enters at once into competition with market-gardeners of long experience, and cannot hope for success until he has learned to produce and market crops as cheaply as his competitors, and just as good. If the city man knows little or nothing about farming, it would be advisable for him to hire a competent farmer to manage the place for two or three years, and work under him until he has learned the business.

The kind of products to be grown depends on the location and on one's personal liking. The choice of the kind of farming may make all the difference between failure and success. Floriculture may be too expensive, because glass houses are necessary. Poultry-raising requires close figuring and very special knowledge. General farming, orcharding, dairying, stock-raising are hardly advisable for the city farmer of small means. They require considerable land and equipment, and profits come very slowly at first. Market-garden crops and small-fruits will appeal to the average city man. In the right conditions these will bring good returns, $300 an acre, clear of market expenses, being not too much to expect. It must be remembered, however, that berry crops require considerable labor and do not give full results for two or three years. Running notes on the characteristics of one market-garden combination, condensed from the writer's experience, will suggest some of the possibilities when the natural conditions are good and the man has learned the business.

Asparagus, early and late tomatoes, cabbages, peppers, melons and sweet corn go well together. These, with the exception of asparagus, furnish marketable products the season planted. Asparagus, though requiring two or three years before bringing full results, is a good crop to grow, netting $200 to $400 per acre under the right conditions. The early tomato is a valuable crop if properly handled. The beginner will do well to purchase his sets ready for planting in the field, rather than try to grow them from seed under glass. However, with a little care, a few plants may be started from seed in a box in the kitchen. If there is a ready market for the crop it may net the grower $250 to $300 per acre. The late tomato, though more cheaply grown, sells for less money. When near a good market, cabbage may net $75 to $300 per acre. It can be grown from early to very late in the season. Peppers pay well if there are many foreigners to provide a market. The plants are started under glass and transplanted to the field when all danger from frost is past. The crop is mostly picked green, especially during the early part of the season; during August and early September it is usually left hanging on the vines. As soon as the cool weather comes the market begins to take the peppers in large quantities, both ripe and green. The crop is then hurried off before frost. The crop is easily grown and handled, and yields $100 to $200 per acre. The muskmelon, since the advent of the blight, is a risky crop for the beginner to grow. Sweet corn is a good crop, and, while it does not yield such large profits, it is produced at a minimum of cost, and is rather sure.

The city man who is contemplating farming must look ahead and see that he has sufficient capital to equip the place and carry it until returns begin to come. He must remember that the first essential to success in farming, as in any other pursuit, is an intimate knowledge of the details. If he is wholly new at the business, he will be likely to have many discouragements the first year or two: this will show that he is learning. He should not be disheartened. The business will require continuous and studious attention, as will any other business that is worth the while. As soon as he begins to enjoy the working out of the problems and to feel that he is mastering them, he will be on the high road to success.

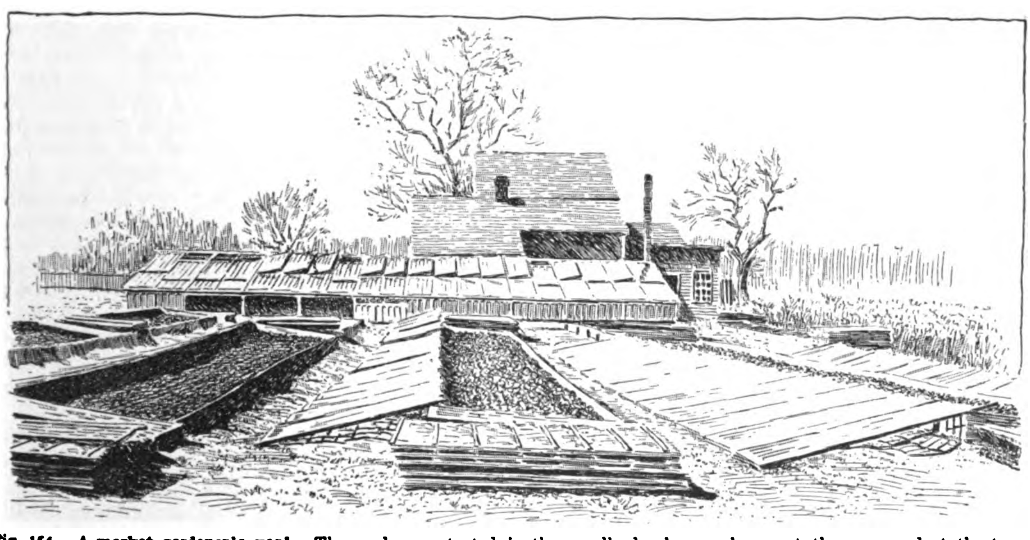


Fig. 154. A market-gardener's yard. The seeds are started in the small glasshouse shown at the rear, and at the transplanting stage the plants are placed in the coldframes, where they remain five or six weeks. The glasshouse is roofed with hotbed sash, and it is heated by a modern hot-water system. (C. C. Hulsart.)

SUGGESTIONS TO A PROSPECTIVE FARMER ON ORGANIZING THE BUSINESS.

By *Harry B. Winters*

An eminent public man said to the writer not long ago that there are three great agricultural opportunities in North America just now,—the rice lands of Texas, the timber lands of Oregon, and the wheat lands of Northwestern Canada. This is undoubtedly true, so far as investment in new lands and the development of them are concerned; but there is good agricultural opportunity wherever crops can be grown and a good market can be found. A good and competent man, understanding his business thoroughly and giving it consecutive personal attention, can make the land pay almost anywhere. The writer is one of those who have gone from the town to the farm. As a partial preparation, he took a short course in an agricultural college. This course has been of the greatest help, and the writer regrets that he did not have a longer one. If a man intends to be a really good farmer, he must have all the helps he can get in the way of advice from experiment stations, colleges and books, and association with men. As this writer lives in New York State, his remarks will necessarily have an eastern man's point of view; but the principles and advice should apply anywhere.

Specialized farming offers the best rewards. The new farmer should be sure that he chooses a location suitable to his tastes and to the special kind of farming in which he means to engage. The most important single thing is to determine what this kind of farming shall be. In many cases, however, the prospective farmer is limited somewhat narrowly in his choice of a location; if that be so, then, having chosen the farm, he must study its adaptabilities very carefully and decide on a kind of business and a type of organization that will fit it. The writer found himself with a farm chosen for him. He has developed a business in the making of certified milk, raising pure-bred cattle, and growing seed oats. Later on, he may add seed corn and first-class draft-horses. If one wants to take life a little easier, he would leave out the making of milk. Beef-cattle and draft-horses are profitable to the man who knows how. Raising good seed of the staple crops of the region is also profitable and is not so confining as the producing of milk. There are also great possibilities in the fruit business; but if one goes into orcharding, he will have to wait for the returns.

Whatever is undertaken, the only profitable course is to produce good stuff. Have high-class products and put your name on them. Make people proud to use these products. Having produced the things, take extra care as to where they are sold. Do not put silk on the calico counter.

How much land to purchase is a personal question. It is usual to advise the buying of a small farm, but what is small for one man may be large for another. Much depends on how much money one has, and on his ability to handle large problems. From an investment point of view, one may safely be advised to put one-quarter of his money into well-drained and good-conditioned land and buildings; one-quarter into live-stock, machinery, equipment and working capital; one-half into first-class bonds, or other dividend-paying property. In this way he would not be jeopardizing his entire capital, and he would be able to add more land and equipment if the business developed. One should be careful not to load himself with poor soil. When it comes to judging the soil, it is economy to ask the advice of a man who has had wide experience and has himself made a success of farming. Money expended on first-class expert advice is always well-invested.

Perhaps the most profitable way to continue this discussion is to consider specific cases. The writer has in mind certain pieces of more or less hilly land within his radius.

(1) Here is a farm of 100 acres that sold recently for $1,000. The buildings are rather poor, but a man who is handy with a saw and hammer could get along with them. If the writer had this problem, he would consider buying a few choice pure-bred cattle, with the object of making butter to sell to discriminating persons. The skim-milk would be fed to the calves. The offspring of these cattle would be worth considerable money year after year. One might not be able to secure as good prices as the big breeders, but he would be able to do very much better than he would if he had common stock. This farm also could raise good grain to sell to neighbors for seed. If kept free from debt, the business should gradually prosper.

(2) Another farm of 100 acres has just sold for $3,000. The location is good, the house first-class, barns fair. The place is three miles from a village of 5,000 people. It joins the farm of a judge of the Supreme Court, a fact that is worth much in the opportunity it gives a man to come in touch with affairs and questions outside his own sphere. This also is a good place for pure-bred cattle and for seed grain. It lies alongside the railroad, and it might be advisable therefore to try certified milk. This farm ought to make money from the beginning.

(3) Ten miles below is a farm of 240 acres, that probably can be purchased for $12,000. It was once owned by a railroad contractor and was called one of the handsomest farms in the county. The land is good. The buildings are now poor. It is about three-quarters of a mile from a small village. Railroad facilities are excellent. This farm is large enough to compare with good breeding establishments, and large enough also, to be interesting to a man of ability and energy. With two or three good foremen, this farm could easily be made a money-maker. These foremen should develop different kinds of enterprises or take different parts of a large business. Like other farms in the general region, it is primarily a grazing proposition; but part of it could be developed to seed-grain production, some of the hills to export apples, and perhaps some of it to potatoes or other special crops.

(4) Another farm contains 400 acres, that

can be purchased for about $30,000. It is fertile river-bottom land, located in the outskirts of a small city. The buildings are one-fourth mile from the end of the trolley line. There is a good stone farmhouse, and two or three tenement houses. The barns are too large and are poorly planned. Here is a property that is capable of developing a large and dignified business, and we may well let our imagination loose on it. The farm is capable of keeping over 200 head of cattle and horses. Here is a good place to make certified milk, and to develop a fine large breeding establishment. It is within a few minutes' ride of good hotel accommodations. The private road from the end of the trolley runs through the center of the farm. Suppose the farm buildings were placed along this road. First would be the office where the business transactions of the farm are conducted. Here would be a supply of small tools and repairs of every sort. Tools that the farm is through with for the season are brought here and put in perfect repair for the next year's work, and stored until wanted. Perhaps a few of the most useful tools on the farm are kept on hand. Here is the purchasing department; everything that comes to the farm is weighed and checked up. This is also the sales department; everything that passes off the farm is charged here; second-hand tools are kept for sale, and perhaps some new ones; here the help is employed. This is the farm headquarters. Here curiosity-seekers and idle persons find it necessary to procure a pass before they are allowed on the farm. It would not be wise to make it disagreeable for any one to visit the farm, but it also is not wise to make the farm a picnic ground. Some men who have done remarkable farm work have been driven out of business by visitors. If it seems wise to establish a visiting day, do so, but do not let the public interfere with the farm work. If a man wants to see one of the employees, it may be cheaper to call the employee to the office by telephone than to let the visitor go to see him. Run the farm on business principles. If a customer comes to this office and makes his wants known, how convenient it is to take him down the road until we come to about the middle of the first 200 acres: here is a barn filled with about 100 high-class milch cows, every cow registered and a good producer. This barn is equipped for making certified milk. Neatness and cleanliness are everywhere apparent. In charge is a man who knows how to produce clean milk and plenty of it. The field work on this farm is in charge of an outside foreman, who makes it his business to grow the crops needed in this barn on the 200 acres surrounding it. The farm is so planned that the corn-field, the oat-field, the hay-field and the pasture center at this barn. One does not have to draw the crops far and the manure is applied within short distances. The persons who work on this farm the year round live near by. The buildings are scattered at safe fire distances, but along the road line, with sidewalks and village conveniences.

Still farther down the road of this complete farm we come to the second barn, about the middle of the second 200 acres. This barn contains dry cows and young cattle for sale. Here are the best bulls, whose get are in demand; here are record cows whose offspring are much sought by the best breeders. Here official milk and butter records are made; here we may hold annual sales, bringing customers from long distances. The man in charge is an experienced breeder and maker of official records. His entire time, energy and thought are taken up with this work, and he is backed up by a wise, long-headed owner. When he has completed the record of a cow, he turns her over to the certified milk man, who keeps her until she is ready to go dry, or wanted for another record. The field work on this farm is again in charge of an outside foreman, who grows the crops needed in this barn. The men doing the work on this farm the year round live near by, as before. We will suppose that the business outgrows these 400 acres. The unit is established. The most difficult work is done, and it will not be hard to purchase 200 or more acres elsewhere and establish as many certified milk barns or breeding barns as seem profitable. There is a great inducement for each foreman to do better than the other; make their conditions as nearly equal as possible and perhaps give them a share in the profits. If Mr. Owner wants plenty of time quietly to work out the problems that such a farm originates, let him put a superintendent in charge of the office, go into the village and buy

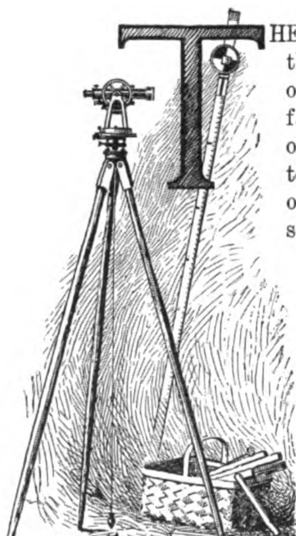
Fig. 155. Homestead of a dairy and grain farmer in southern New York. (The Winters farm.)

that magnificent place with splendid old trees and its lawn of five acres running from the street to the river-bank. Here he may be able to work out the farm problems even more successfully and perhaps make more money than by taking the actual overseeing of the labor. When one has a hard problem to solve, he needs a quiet place, not forty men around him asking questions that perhaps some one else can answer as well or better. Here there will be some relief from details, and the perplexing questions will look simpler and clearer. Mr. Owner will be in reach of libraries, a short distance from churches, banks, and large business enterprises and, best of all, in contact with ministers, teachers, bankers and business men who become friends and advisers. This may not be a poor man's picture, but it outlines an excellent business enterprise that is worthy any man's best endeavor.

(5) The above example (No. 4) is an ambitious one, but farming needs ambitious enterprises and it can support them. Capital can be safely put into farming, if there are competent managers. But the man who has no capital also asks for advice. The fifth example is that of a young man who lost one foot in an accident. He had very little money. He was a lover of cattle. He purchased a few acres in the outskirts of a small city and took to the producing of milk. He buys fresh cows and sells them when they go dry unless they prove to be of superior worth. He makes no attempt to breed cattle. He keeps everything scrupulously clean, feeds carefully of wholesome foods; and the milk sells for more than the average retail price in that city because the patrons recognize that it is worth more. It is a milk business; but the man raises a few strawberries which he sells on his milk route. He also has a fine flock of hens, and sells the eggs for a good price because they are strictly fresh and always clean. He also gets an advanced price for broilers, because they are fed with clean food and kept in good quarters and are delivered fresh when his customers want them. This man is living well and is making some money. The business could be extended. It is not a large enterprise, but it illustrates what a man can do under adverse circumstances.

CHAPTER IV

THE PLANNING OF A FARM



THE PLAN OR ARRANGEMENT of a farm involves two sets of questions: those that concern the practical working or administration of the farm itself, or farm management; and those that are involved in the relation of the farm to the community, or rural economy. Discussion of the former or internal set of problems is intended in this chapter, for these are technical agricultural questions. The influence of the farm on the community, or the external questions, involves subjects of general economics and of social relations. However, the two phases of the subject cannot be wholly separated, since the plan or layout of a farm is modified fundamentally by its size and also by labor supply and other external conditions.

A discussion of the size of a farm at once raises far-reaching public questions. Shall a farm support only one family, with the necessary hired help, or shall it be organized on a much larger basis and support many families under one ownership and management? Or, again, shall it be in any way coöperative? To state the subject in another way, Is it desirable that every farm family shall own land, and be self-supporting in the sense of making a living from the conducting of an independent and isolated business? Probably most persons will answer this last question unhesitatingly in the affirmative. We have been accustomed, in the United States, to regard individual ownership of farms as a necessary part of democratic institutions: the farm is the one place in which it would seem that individual independence of social position can be secured. Without desiring to argue the question or to express any judgment on the subject as a whole, it may still be worth while briefly to examine some phases of it.

The older farming, at least in the northeastern states, was practically a completely self-regulating business, comprising not only the raising of food and of material for clothing, but also the preparation or manufacture of these products. The farmer depended on himself, having little necessity for neighbors or for association with other crafts. The system was a kind of small or individual feudalism. In the breaking up of the old stratification under the development of manufacture and transportation, and the consequent recrystallizing of society, the old line fences still remained: persons clung to "the farm" as if it were a divinely ordained and indivisible unit. This atomic conception of the farm settled the business into rigidity. The "abandoned farms" are forsaken atoms; and there are many other atoms, large and small, to which the owner still clings with a forlorn hope, becoming a slave to the area that lies inside the boundary fences. The rehabilitation of a region of so-called abandoned farms must be molecular, in most cases. The traditional boundaries must be disregarded. The land need not be aban-

Fig. 156. New farm organization in New England.—Several fields have been united into one.

doned, even when the farm is abandoned. A farmable and manageable area must be assembled, quite irrespective of the party that owned it a generation ago, bringing together those lands on which one may establish a really effective farm business. In many parts of the country, the line fence is the greatest obstacle to the development of agriculture.

If the old farm must be taken into a newly assembled system, perhaps the farmer himself may also change his relationship to land. Because eighty acres or one hundred and sixty acres can support a man and his family, it does not follow that this is the best arrangement either for the man or for society. Not every farmer has either the executive ability or the skill to enable him to handle a business of his own; and the great majority of men at best can manage only a small business. Even with all our education in agriculture this will remain true, or relatively true. It will not do to argue that a farm business should be large in order that the farmer may become wealthy, for wealth (as now-a-days measured) is not the most desirable end in farming; but a business must have a certain volume and momentum in order to make it effective in itself and to develop the best results for the community. It is not true that "a little farm well-tilled" necessarily develops the best farming. It develops great skill of a certain kind, but it does not train managership or generalship: the little farm is too small a field for certain types of ability of the first order. The best agriculture will develop under the best leadership; and it is a question whether strong leadership is likely to arise in a region of similar-sized farms.

Unless all signs fail, the chief feature of the new agriculture is to be the development of leadership, as it has been evolved in other occupations and trades. We cannot expect to apply the discoveries of the new science or the benefits of the new education without a new kind of leadership. This is likely greatly to modify the existing order. For the past generation and more, agriculture has been undergoing a struggle for existence. The struggle has not been even-handed, for the farmer has been disadvantaged by disabilities and oppressions that do not belong normally to his business; but the net result is the elimination of the least efficient and the least adaptable. This process is likely to continue, and we shall see decaying agriculture alongside of advancing agriculture. The unadaptable farmer, if he remains in the business, will be bound to have dependence on the progressive farmer. Leadership may come about in several ways: declining farms may be purchased outright and assembled into large holdings; the farmer may retain ownership and take part in a coöperating system, as in the cheese-factory and butter-factory regions; the relationship may be purely educational, the weaker man in the community looking to the stronger for advice and guidance in the management of the farm. In whatever way differentiation arises, the process will modify not only the size of the farm but the internal organization of it. In other words, it is doubtful whether farms are to retain the economic and social separateness that they have had in the past. It is a question whether the increasing difficulty in obtaining farm labor is to be overcome merely by securing labor here and there for existing kinds of farms; or whether some of the embarrassment is to be met by farmers working for other farmers; or some of it by such a reorganization of the business as to provide overseers for cheap labor operating in groups, or at least under control. Farming can not expect to compete with other business in the demand for labor until it pays a comparable wage; and it is a question how far it is possible always or even usually to secure this wage, together with the increasing necessities of better living, from the present one-family farm.

On the other hand, there is undoubtedly to be an increasing place for the very small farm. The small, intensively tilled farm will be near centers of population where the farmer can handle his own market; and high-class specialties will be produced. Such a business enjoys great economic independence. It demands high skill. It is to this kind of farming that the popular fancy seems to run, notwithstanding the fact that few persons possess the requisite skill and knowledge of special detail to make it a success.

Another type of small farm is that on which the proprietor expects to perform all the labor himself, with small equipment. These are one-man farms, and the farmer is essentially a laboring man. All the income is derived from the products that one man can secure: there is little organization and no profit on other men's labor. Such farms are usually on low-priced land and are devoted to the universal staples in which risk is reduced to the minimum. They rarely develop the best possibilities of farming. Their policy is narrow and traditional. This kind of farm is very numerous. Here is the seat of much of the slow and poor farming.

It is possible to manage satisfactorily a farm of one hundred and sixty acres or less with comparatively little outside help, if the soil is good, the equipment ample, if much general live-stock is kept and little land is maintained in tillage. In good farms of this class the proprietor expresses his organizing ability largely in management of tools, machines, teams and cropping schemes. If such farms do not develop the greatest possibilities of the soil, they still may be profitable and they contribute to a wholesome and attractive social order.

On the other extreme is the large so-called "bonanza farm" of the Great West, characteristic of a new country. These farms are in process of disintegration. Usually they are poorly farmed, although many of them are examples of good business organization. Under the social and economic conditions that obtain, they are too large.

The novice is likely not to see the larger questions of plan and policy, but to think first of raising enormous crops. He is always attracted by "bumper crops." Emphasis has been laid on this phase from the first by the agricultural colleges and the agricultural press. Heavy crops are of course essential; but one must be sure that they are worth what they cost, and that they mean something to the general scheme of the farm business. The American small farm has not raised the question of farm organization as it has been raised in countries of managed estates; but the primary consideration in any farm, small or large, is to analyze the business and then to organize it. The American farmer has succeeded because land has been new, rich and cheap: in farm organization and management he is undoubtedly distanced by his European compeer. Naturally, the Middle West and the Farther West are to strike out new lines; and because of similar economic and social conditions, the East is to look to the West rather than to Europe.

There is another class of questions in the organizing of a farm that some time must be considered in the interest of society: this is the devising of such farm plans as will make the entire farm attractive to a sensitive mind; and in time the artistic appearance of the entire countryside will be considered worthy the attention of all farmers. The layout of the farm may be made to serve esthetic ideals without depreciating the economic value of the farm or interfering with its administration: rather, such layout should aid the utilization of the estate, since the artistic is that which also is fit. This subject, however, will find a fuller discussion in Chapter IX.

Plate IX. Farm lands in eastern Tennessee

It is difficult to state principles underlying the proper layout and organization of a farm, since the plan must conform to the person and to local conditions. Perhaps the best that can be done is to give examples, letting the author state his reasons. The leading points to consider are perhaps the following:

The adaptation of the plan to the kind of farming that is to be pursued;
The best utilization of the different soils and exposures and natural features on the place;
The economizing of time and labor in reaching all parts of the farm;
The best location of buildings with reference to efficiency of administration;
Such layout as will best provide for rotation and the maintenance of fertility;
A proper proportion between the different parts, as between tilled and untilled land, forest and open, meadow and pasture, forage crops and grazing, orchards and annual crops;
Provision for the necessary live-stock;
Such shape and size of fields as will best lend them to economical working;
Provision for the more personal parts of the place, as gardens, yards and ornamental features;
Development of the artistic or attractive appearance of the entire estate.

THE LAYOUT OF THE FARM

By *W. J. Spillman*

When the United States government made provision whereby citizens of this country could secure land under the homestead law, the principle which governed in fixing the amount of land that one individual might preëmpt was that the area should be sufficient to support an average family in comfort. At that time settlement was going forward in the Middle West, and in that section it was then considered that a quarter-section, or 160 acres, of land was a suitable area for a homestead. The same principle applied to irrigated lands in the West would probably result in the area of homestead claims being reduced to something like sixty acres. When applied to the ranges, it should provide range enough to enable the farmer to sell about forty head of two-year-old cattle annually. In order to do this, the ranchman would have to maintain a herd of about sixty cows, which, with their progeny, would make a herd equivalent to about one hundred and forty head. When the ranges will carry one head on ten acres, the range homestead would necessarily be about two and two-tenths sections of land. When the range is so poor that it will support only one head to fifty acres, the homestead should include eleven sections.

The interests of the whole people are best served when the size of the farm is governed by the principle above outlined. The ideal is many small farms owned and operated by contented and prosperous farmers whose families enjoy the comforts of life, rather than a few large estates occupied by an ignorant, discontented and ambitionless tenant class. The latter are inimical to our democratic system of government. The old idea that the man with the hoe must be little above the brute is thoroughly disproved by experience in this country. There is no more self-respecting class than the small, prosperous proprietors. It is only when the tiller of the soil must carry on his back a mercenary and piratical aristocracy to rob him of the legitimate efforts of his toil, that he must be the unthinking animal pictured by Millais. Let us take, then, as the ideal the small farm that produces an abundance of vegetables, fruit, meat, forage — in fact, everything needed on the farm that can be economically produced at home, with enough of all these and some other money crops to sell to supply the needs and the desirable luxuries of the family, and provide surplus enough to educate the children and leave something for the proverbial rainy day.

In those sections of the country where markets are available and where the prices of all kinds of farm produce are satisfactory, it has been demonstrated that a family can live well on ten acres of properly managed land. It is only the exceptional man, however, who has the executive ability for the

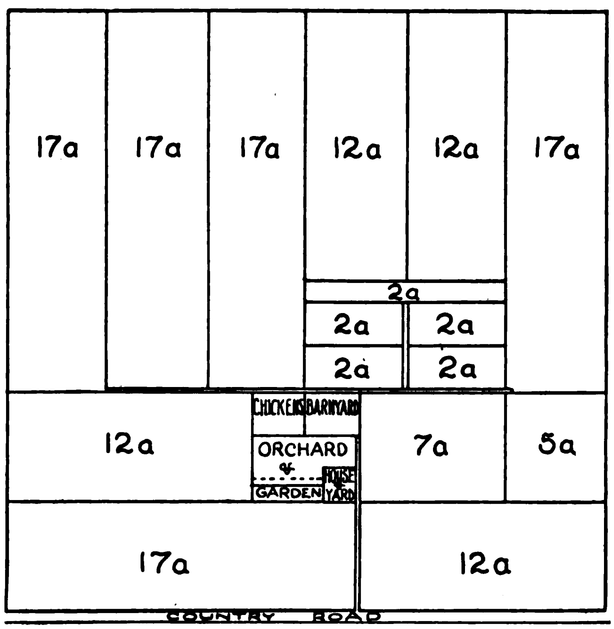


Fig. 157. Suggested subdivisions of a farm in the prairie region devoted to dairying, hog-raising and poultry; 160 acres.

highest type of farm management, so that the average small farm must be considerably larger than this.

There is one point in the management of a farm that is not generally understood: the cost per acre of running a farm increases with the size of the farm. The larger the farm the more time is lost in going to and from work and the greater the distance the manure and the farm products must

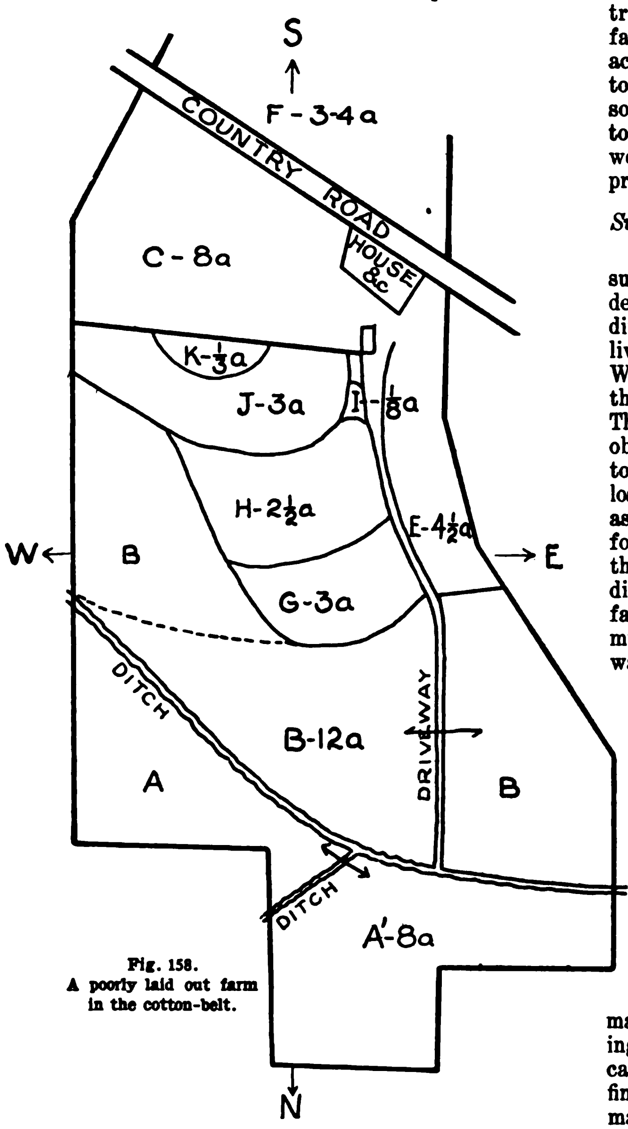


Fig. 158.
A poorly laid out farm in the cotton-belt.

be hauled. Whenever it is practicable, particularly in the management of dairy farms, the expenses can be much reduced by dividing large farms into units, each supplied with its own buildings, work stock and farm implements, only the salable products being brought together at a central point. It is rather fortunate than otherwise that the expense of management does increase with the size of the farm, for this fact checks the tendency toward large estates occupied by tenants.

Except in sections where the land is comparatively level, the subdivision of a farm into fields must be determined largely by the lay of the land. In nearly all parts of the country, every farm has more or less land not suitable for cultivation. As the topography is not the same on any two farms, it can be considered only in a general way in this connection. The principles involved can be illustrated in cases in which the topography is not a factor and in which the soil is uniform in character, and leave the application of these principles to the farmer. Occasionally the character of the soil on different parts of the farm varies so much as to render one field unadapted to crops that will grow well on others, but for obvious reasons no general principles can be given to cover such variations.

Subdivisions.

For most types of farming it is desirable to subdivide the farm, to permit of a more or less definite rotation of crops. The number of such subdivisions depends on the crops to be grown, the live-stock to be kept, and the rotations adopted. We can only assume a plan and work to it, leaving the individual farmer to suit the plan to his needs. There are a few general principles that should be observed in laying out the fields. (1) It is cheaper to cultivate long rows rather than short ones. The loss of time in turning when cultivating short rows as compared with very long rows may easily account for a difference of as much as 30 per cent in the cost of tilling a crop. For this reason, the subdivisions, so far as possible, particularly on small farms, should be long and narrow when there is much tilling to be done. (2) The fields and roadways should be so arranged as to permit of easy and direct access to all parts of the farm. (3) The buildings should be so situated as to avoid long hauls in carrying out manure and bringing in crops. In the case of very small farms compactly arranged, it is desirable to have the buildings near the roadway, usually at one side of the farm. If the farm is cut up into small tracts separated by hills and valleys, the site for the buildings should be chosen with a view to minimizing the distance to the fields. On medium-sized and large farms and on small farms consisting of detached areas, the buildings should be more centrally located. (4) It has already been suggested that large farms may very properly be cut up into units, each working more or less independently of the other. In such cases there should be a central point for gathering final products preliminary to their preparation for market. Even on the large grain farms of the West subdivision into rather large units is desirable on the score of economy of operation. This plan requires very little more outlay in buildings and machinery than would be necessary in handling the farm as one large unit, and the saving in various ways appreciably reduces the cost of operation. (5) The subdivision should be such as to provide for good rotations, as discussed in the next paragraph. (6) In addition to the greater economy of operation with well laid-out fields, there is the further consideration of neatness in the appearance of the farm. Straight fences, straight rows, and properly arranged fields and roadways are as much a source of legitimate pride to the farmer as are the beautiful architecture and the well-kept lawn of the country or city home. A little attention to details of this character adds much to the charm of country life. Such things indicate the state of culture in a community.

When rotation of crops is practiced, it is essential that the subdivisions of a farm should be of such size as to permit approximately equal quantities of

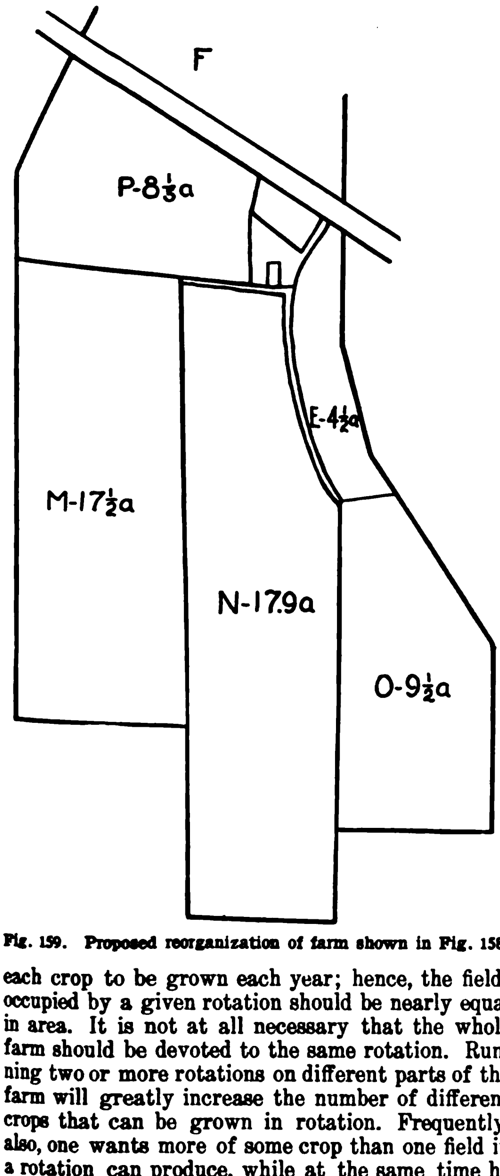


Fig. 159. Proposed reorganization of farm shown in Fig. 158.

each crop to be grown each year; hence, the fields occupied by a given rotation should be nearly equal in area. It is not at all necessary that the whole farm should be devoted to the same rotation. Running two or more rotations on different parts of the farm will greatly increase the number of different crops that can be grown in rotation. Frequently, also, one wants more of some crop than one field in a rotation can produce, while at the same time he wishes to avoid growing this crop too often on the same field. By means of two rotations on two sets of fields of different size, one can adjust yields to requirements without growing the same crop too frequently. Again, on fields near the barn one may depend more on manure to maintain fertility and can dispense with legumes and other green-manures, while these restorative crops may be made to take the place of more or less manure on fields at a greater distance from the barn. The number of fields required for the proper conduct of a rotation is the same as the number of years covered by the rotation. Thus: a four-year course should occupy four fields, in order that each crop in the course may be grown every year. While these fields should be about equal in area, or at least in producing power, it is not essential that each of them should consist of a single tract. Any one or all of them, if necessary, may consist of several detached pieces of land. In fact, such an arrangement is frequently desirable, for it provides the opportunity of separating parts of a crop to be used for different purposes. Frequently, also, one of the fields in the course may consist of small areas of different crops, and the division of the fields in the separated tracts gives the opportunity to use these crops for purposes for which they could not be used if they were all grown in the same enclosure. It is hardly necessary to state that rigidly fixed rotations are not always desirable. The system should be sufficiently elastic to permit of dropping in other crops wherever the failure or temporary undesirability of a crop may render a change advisable. We cannot, however, take cognizance of such changes in laying out the fields, for they depend on future contingencies, which cannot always be foreseen.

In establishing a new farm, especially in prairie regions, it is easy enough to secure a desirable arrangement of fields. Fig. 157 shows an arrangement of such a farm. It is not contended that this arrangement is ideal, nor that it is the best for any particular farm; but it is one that illustrates the principles that have been discussed above. The area of this farm is 160 acres, and it is supposed to be devoted to dairying, hog-raising and poultry; and the subdivision of the farm is intended to fit it for the purposes stated. If the farm were much larger, it would be desirable to cut it up into units more or less independent of each other; and, in fact, it might be desirable to divide a dairy farm even of this size into two, three, or possibly four smaller units.

In the first place, the barnyard (Fig. 157), which occupies one acre, and is supposed to provide room for barns, silos, machine-sheds, and the like, is situated as near the center of the farm as is convenient, and the roadways are so arranged as to give convenient and near access to every field of the farm. The house and surrounding lawn are given one-half acre. Adjacent to the house are a garden of three-fourths of an acre, and an orchard of one and three-fourths acres. To the right of the barn lie two small tracts, which may be subdivided to suit, either as shown or into two six-acre tracts. These will be convenient for growing soiling-crops and for use as calf-lots; and they may alternate for these purposes as often as is desirable. Back of the barn and the seven-acre lot is a ten-acre tract, which in the plan as drawn is intended for hog pastures. It is shown divided into five two-acre subdivisions, so arranged that all of them open into a central lane, the lane forming the roadway from the barn to the two fields in the rear. This ten-acre tract may be used for various purposes; on the writer's farm it is subdivided as shown, and used for hog pastures. One of the fields is in permanent sod, and the other four are used for a rotation of crops, all of which are used for hog pasture, and they provide abundant green pasture for forty to sixty head of hogs throughout the season.

The remainder of the farm consists of five seventeen-acre fields, all arranged so as to be long and narrow and thus economical to cultivate; and four twelve-acre fields. Throughout the larger part of the country in which the type of farming here considered prevails, the five seventeen-acre fields might be run in a rotation of corn, oats, wheat, timothy and clover two years. The four twelve-acre fields might be devoted to the same rotation with the wheat left out. This would give a small acreage of wheat every year, which it is desirable on many farms to grow, the remainder of the crops produced on the farm being available for stock-feed.

Numerous modifications of this plan might be made. For example, the two seventeen-acre fields at the left might be put down in alfalfa. The next seventeen-acre field and the adjacent twelve-acre field could be combined into one; the two fields to the right of these into another; and the two fields in the lower left-hand corner of the diagram into another; thus giving three fields of twenty-nine acres each, on which a rotation of corn, oats and clover might be run. This would leave the three tracts in the right-hand lower corner of the diagram for soiling-crops, pastures, orchard, truck-crops, and the like.

A good well anywhere near the house, with a little piping, might supply water to the house, barnyard, chicken-runs, and to the lane in the field subdivided for hog pastures.

A much simpler arrangement of this farm could be made, provided only one rotation were to be run; but it is deemed sufficient to show the more complex one only.

Instead of having the opportunity to plan a farm de novo, the more usual problem of the farm engineer is that of remodeling an old farm. Fig. 158 is a diagram of an actual farm which has been remodeled by the Office of Farm Management of the United States Department of Agriculture. The layout of this farm, as shown in the figure, is typical of the small cotton farms of the South. In that part of country, on farms that are to be devoted to cotton and stock-raising, the most desirable rotation is cotton followed by corn and cowpeas, this followed by oats as a winter crop, finishing with a crop of cowpeas for hay. This is a four-course rotation that requires only three fields, as one of the crops is a winter crop in the South. The rearrangement of the farm which has been suggested by this Office is shown in Fig. 159.

It will be recognized that the problem of making a satisfactory arrangement of this farm is complicated, first, by the peculiar outlines of the farm, and, second, by the topography and the presence of the country road cutting off a small corner of it. An inspection of Fig. 159 will show that by treating the fields marked P and O as two parts of one field, the main body of the farm may be divided into three approximately equal areas, and thus adapted to the three-year rotation outlined above. The small strip of land marked E is separated from the field N by a rise of ground on which a roadway runs. The new arrangement permits access to all of the fields by short roadways, and leaves the topographically segregated field E for use as a truck-patch or for growing soiling-crops or whatever is desirable. The small tract lying across the road from the main body of the farm may also be utilized for any miscellaneous crops that are needed. The rearrangement permits the main body of the farm to be divided in such a way as to admit of economical cultivation. This arrangement, of course, assumes that the open ditches shown in Fig. 158 are to be covered.

THE REORGANIZATION OF FARMS IN NEW ENGLAND

By *J. W. Sanborn*

The representative New England farm contains approximately 150 acres. The homes are ranged along the roadsides and close by them, economizing both land and steps. The ideal business location has often been sacrificed to the social instinct in this location. The hills, sometimes stretching away into ridges that dip each way into valleys, represent the most valuable land, and so it happens that, passing over them as they do, the roads cut the best land. Fields usually are grouped about the buildings. For modern machinery these are far too small, and are enclosed with boulder walls that repel removal. They are, however, to a limited extent giving way to mechanical necessity. Pastures occupy more remote sections of the farm, being connected, when cows are kept, with the barnyards by lanes or driveways walled in. Woodlands occupy the more distant parts of farms, except where the repellant character of the land invites them elsewhere. The rocky character of some sections of most of the hill-farms has prevented the close-calculating Yankee farmer from following this mechanical laying out of his farm. He seldom locates woods with reference to windbreaks and landscape effects. New England owes its scenic charm to the farmer's necessity rather than to his cultivated forethought, so far as trees lend their influence to the landscape.

For a generation there has been a decided drift toward centralization of farm-buildings, and, as shown in Fig. 160, practically all the main buildings are being placed under connecting roofs. Often the farmer does not go out-of-doors in making the rounds of his indoor labor. Steps are avoided, and in inclement weather the farmer labors in the barn and wood-shed. Insurance is cheaper than labor, and comfort more important than bank accounts.

The withdrawal of the youths and capital for the settlement of the West as from no other section, and the secondary great movement to the centers of enterprise to found new industries and to reorganize old ones, created a crisis in New England farming. Its result was a contraction of operations. Tillage crops decreased and grass farming extended. The rotation became corn, oats or barley, clover and timothy. The timothy crop was extended for five years at least and often to an indefinite time. Manuring occurs but once in the rotation,—for the corn crop, and in heavy amounts, thirty-five to forty-five tons. Pastures are left to nature, as are the woods.

The contraction of tillage and the reign of grass and low-pressure farming, the passing over of old fields to pastures and of pastures to bushes and woods, has brought the division of the upland and typical hill granite soils into thirty- to forty-acre tillage areas. One-half or more of the remainder is in pastures, the remainder, ordinarily the roughest land, being woods.

The repressive causes that have tended to inertia in agriculture are passing away, and a new hope is inspiring farmers. Freer application of capital, labor, machinery, chemicals and increased tillage, are creating a new era in eastern agriculture. This article will treat, then, as more in keeping with present tendencies, of the type of things to be aimed for rather than the type developed under passing conditions in New England.

Buildings.

Those constructing new buildings should locate them as central to farm operations as possible. An acre eighty rods from the buildings requires, in a rotation period, some six miles more travel for the men than one close to the barn, and five miles more annually for the team. This represents, in interest on land at 5 per cent and labor at $1.25 per day, $25 per acre. The close-by acre is worth, then, for use $25 more than the one eighty rods away. If the house is in the center of a 150-acre farm, the most remote acre would be less than one-third the distance away than when the house is at one end of a 150-rod or 160-rod farm containing the same area.

On the same principle, the present tendency of New England farmers to concentration of buildings is commendable, both for the economy of steps and the comfort of work in inclement weather. The round barn conserves labor, but not the exchequer. The square barn economizes both in first cost and annual labor bill, as compared with the common rectangular barn.

The conservation of labor should be applied in the laying out of the fields, pastures and woods. The inner circle should be fields, the second circle pastures, and the remote land woods. While Nature on the hills has often predetermined which shall serve each function, art may often improve on Nature when applied to the service of man.

It would be wise to invest, as seen, $25 per acre, if necessary, in subduing to tools near-by pasture-land in exchange for remote field-land. An exchange can often advantageously be made with the woodland; this statement is made from experience.

Fig. 160. Concentration in farm buildings. Such arrangement economizes time and strength. It is particularly adaptable in a cold climate.

The mistake is often made of developing fields on a grade above buildings for ease of crop-housing. It should be remembered that for each ton of dry food fed to animals two and one-half tons of manure should be drawn out, as determined by investigation.

Before passing from the relation of the farm lay-out to the buildings, or of the buildings to the land, we may consider the laborers' cottage. No representative farm should be without such a cottage as a part of the farm group of buildings. This, too, should be handy, that the chores and viewing the stock the last thing for the night may be done with few steps. The farm cottage relieves the home of an incubus and fixes the man to the farm. It partly solves the labor problem. A representative farm in the future will be, and must be, more than a one-man-power farm if it is to be satisfactory to aspiring youths.

The tillage area.

The vanishing causes that reduced New England farming to the capacity of the owner for labor, and the capital and tillage involved to a minimum, should lead us to question to the bottom the propriety for the future of a system that has robbed the farms of about all market value and has driven the sons and daughters away. The average 150-acre farm given over to staple crops is now a dairy-farm. It does not carry over twelve cows, nor does it sell over 200 pounds of butter per cow at twenty-two cents per pound. Adding to this skim-milk at $10 per cow and the sales of two old cows, a revenue of $688 is secured. Add miscellaneous receipts of $212, and the gross revenue of but $6 per acre is secured. This is less than the rental value of European farms and of good farms in the Middle West, and has no possibilities. It is hopeless.

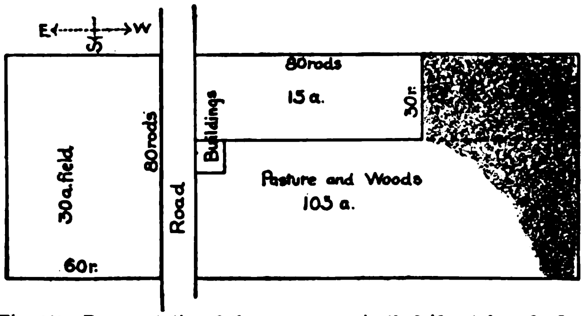


Fig. 161. Representative of the more conveniently laid out farm lands for the East. Woods are often separated from pastures.

The revenue of farms is derived from their tillage areas. The farmer should expand these by contraction of pasture and woodland areas. Each acre thus added has a ten-fold productive capacity, makes a home market for money, gives profitable play to machinery, requires regular labor and expands the farmer's mental activity.

New England farming is professedly and designedly one of small effort. Nothing large can come from contracted operations in any sphere of business activity. For great operations as now conceived in the business world it is not the plea. Rather, a larger use of the mental faculties may be urged in greater pressure on the capacities of the farms in question. Their productive powers are barely touched, and the intellectual faculties in but small part pressed into use in exploiting the resources of the soils.

Crop-rotation, or scheme of farming.

How, then, shall we reorganize the scheme of farming? A fixed crop-rotation embracing all the pasture and woodland available should be adopted. This land must be fitted for machinery. The age of muscle has passed. It cannot compete in New England with machinery elsewhere. Labor of others would and should be involved in the farming. On it only, in farming as in other business, can more than very limited results be secured. A rotation should involve more of the rank-growing annuals as corn, oats and peas, and less of the perennial grass crop. The grass crop gives in New England only about a ton to the acre.

The writer uses an eight-years' rotation, and relates it here not for copying, but as illustrative. It has comprised much of the woods and pasture-land. It runs as follows: Corn for silage, treated with chemicals and manure; oats and peas, chemicals or ashes applied; clover, mineral manures applied; potatoes, yard manure and chemicals applied; Hungarian grass and grain, yard manure applied; timothy, yard manure or chemicals; timothy, chemicals; pasturage, chemicals.

This has the following advantages: 1. It so divides the labor of the farm that it is employed the year round in regular amounts, and made of maximum economic effect. The same is true of the horse-power employed. These factors experience demonstrates to be important.

2. This division of the farm into crops following each other in orderly succession, so divides operations that each part can be well done, and avoids rush periods and those offering no economic work.

3. Each section is adequately fertilized each year and productive crops introduced. A phenomenally rapid increase of crops follows, that involves so free a use of machinery, executive faculties in handling the labor problem, and capital in the prosecution of the work, that a wholly new aspect is given to agriculture in New England, mentally, socially and commercially.

4. Rotations are soil-conservers and soil-feeders. They are dictated by nature's processes, and philosophically founded in varying root-areas of crops; in the differing type of leaves and water-vaporizing powers, and in their varying powers of gathering nitrogen, potash, phosphoric acid and the like from the soil; in their differing weight of roots; in powers of solving soils; in bacterial relations to nitrogen-gathering; to fungous and insect pests, and to other causes. It has been fully shown in field trials, by the writer and by others, that a rotation series gathers more from the soil than a non-rotation series.

The extended demand for plant-food made by a scheme of farming that reverses traditional methods and feeds a far larger area of the farm and all of it every year, must receive a passing notice and defense.

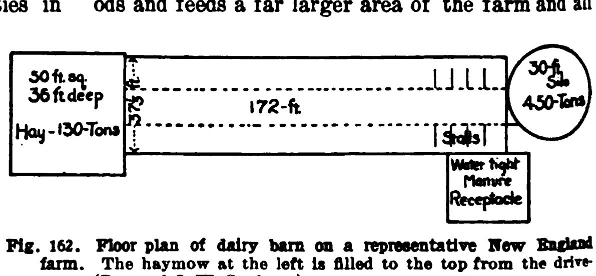


Fig. 162. Floor plan of dairy barn on a representative New England farm. The haymow at the left is filled to the top from the driveway. (Barn of J. W. Sanborn).

1. It will be noted that one-half of the farm is tilled every year. Tillage, in every age and condition of agriculture, has been shown to be an indirect process of manuring. Science has shown it to be a means of increased solution of soils.

2. Irrigation, when available, as it is in far more cases than it is popularly supposed to be, is not only an antidote to drought, but a direct source of plant-food in its cheapest form. This source is availed of in the writer's experience.

3. Muck is used both as a source of humus and of nitrogen. This material is in every section of New England.

4. Purchased nitrogenous foods are an economical source of the increased nitrogen supply required, and limit the direct purchase of this material in the fertilizer markets.

5. Chemical manures are one of the corner-stones of farm cropping thus laid out, and must be heavily drawn upon. They in turn increase the manure supply of the farm. When used with a reduced application of good manure, the effect of each is enhanced and both made profitable.

The writer is fully convinced that a readjustment of crops and their succession, the broadening of operations on the farms now in possession of representative farmers, and greater intensification of farming for the entire area, will place the returns of New England farming alongside of the most favored sections of the world.

TYPES OF FARM ORGANIZATION IN THE SOUTH

By *G. F. Hunnicutt*

The layout of farms in the South has changed much in a generation. Under the old régime, most of the farms were devoted to cotton, and were laid off in simple but magnificent proportions. It was not uncommon to find a fine colonial homestead situated in a grove of oaks; in the rear, a commodious crib and barn, built separately, and generally of hewn logs; a few hundred yards away a horse-power cotton-gin; down near a spring a row of negro cabins, constructed also of hewn logs; then broad outlying cotton fields completing the picture. These plantations were of one thousand to several thousand acres. They varied occasionally from the above description by having buildings constructed of brick, or of lumber when sawmills were convenient. Now the changed labor conditions, the advent of improved machinery, the growth of cities and manufactories, the realization of the necessity for diversification, both for soil improvement and to render the farms self-sustaining, have wrought great changes, and with almost marvelous rapidity the layout of the southern farm has taken on new and better proportions. From the single cotton plantation have come many distinct types of farms, an adequate conception of which can be obtained only when they are considered separately under their natural classification as cotton farms, cotton, corn and grain farms, dairy and stock farms, truck farms and fruit farms.

Another type of farm still common in the South, and representing the other extreme, is the fenced-in small area in the wooded sections, usually belonging to a "cracker" farmer. It is clearly the intention, in such cases, to set off the domain from the forest. Fig. 163. Of course such farms must necessarily be weak economic units, unless combined into larger properties.

Cotton farms and rental systems.

Many old plantations, more or less intact, and smaller farms, are still to be found in the South, the owners of which hold to the old system of growing cotton almost exclusively. They still try to cultivate thirty-five acres to the mule, nearly all of it in cotton. This crop is sometimes planted up to the very doors of the houses, and in many instances the land has been in cotton for fifteen or twenty years consecutively. Occasionally five or ten acres are put in corn, but it receives only the little attention that can be spared from the exacting demands of the cotton. Some of the farmers, who have exceptionally good lands and are good managers, are doing well, and have comfortable homes for themselves and for their tenants.

The tenants were formerly all negroes, but of recent years many of the negroes have moved to the cities and white persons have taken the places on the farms. In some sections, however, the reverse is true, the white people having gone to the towns and left the farms to the negro tenants. These tenants work the land on shares. The systems of tenantry may be grouped under three heads, at least as practiced in Georgia. (1) The "half-and-half" contracts cover about one-third to one-half of the whole. In this system the landowner possesses both land and stock, and furnishes the "cropper" with house, mule (or mules), truck-patch and firewood—also advancing his supplies. Each shares equally in the net proceeds after the cost of fertilizers and supplies has been deducted at the end of the season. On the "half-and-half" arrangement, it is usually agreed that about two-thirds of the area cultivated (or an average of 20 acres per mule) is to go in cotton and one-third (10 acres per mule) in corn. The latter is seldom sold, but divided in kind and retained by both parties—by the owner for the maintenance of his stock and by the "cropper" for food. (2) When the renter or "cropper" possesses his own draft-stock, it is customary, in probably 30 per cent of the total number of contracts, to rent for a "third-and-fourth"—that is, the "cropper" pays to the landowner one-fourth of the cotton and one-third of the corn. As in the "half-and-half" contract, he is furnished with a cabin, truck-patch and fuel, and has his supplies advanced up to "settling day" (Nov. 1), but he feeds his own stock and pays for three-fourths of the fertilizer used for the cotton and for two-thirds of that used for the corn. (3) In the remaining percentage of contracts the land is either rented at a fixed price per acre, according to its capacity and value, or for so many bales of cotton "per mule" (generally two 500-pound bales for 30 acres). A domicile may or may not be furnished with the land, and the renter finds his own supplies of every kind. This is the most variable and elastic of all the contract forms—and generally the most satisfactory to both parties, whenever it can be effected. When the renter has stock, he usually pays what is termed "standing rent," which is 1,000 pounds of lint cotton for each one-horse farm.

As might be expected, these kinds of farming do not tend to develop diversity or stability, and the farm buildings are cheap and scattered about the place to suit the convenience of the tenant. There is no centrally located or well-appointed layout of the buildings, and no systematic arrangement of the lands or crops. Cotton and a little corn are almost the only crops grown. There is usually on such farms a cheap, unpainted house containing four rooms and a kitchen; in the rear, a hundred feet or so, is a cheap barn, capable of sheltering two horses or mules and a cow. On one side of the house is a garden spot, half an acre in extent, a few fruit trees, and then the cotton-field. The fields are irregular in shape and often intersected by gulches and galled spots, while the timber lands often project into them. This makes greatly against the appearance of the farms in the southern states. When cotton was selling low, this class of farmers experienced very hard times. It is a hopeful sign that they are rapidly decreasing in number, and giving way to farming on a better basis.

Cotton, corn and grain farms.

Various agricultural organizations have been advocating diversified farming, with the result that many farmers are pursuing more rational systems. These are following a three-year rotation, as follows: one-third of the land in cotton, one-third in corn, and one-third in grain and hay. They generally have thirty acres to the plow, this giving them twenty to cultivate, which they can work much better than the former large acreages of thirty-five or forty acres. Usually, corn is followed by wheat and oats, the grain by cotton, and the cottoh by corn, which makes a satisfactory rotation. The grain lands are sown to peas, or peas and sorghum when the grain is cut, thus making two crops.

This class constitutes the most independent and progressive farmers. They usually have one hundred to three hundred acres. Many have their lands systematically laid out, and their farms present an attractive appearance. Some have areas of branch or creek bottom on which corn and hay are grown continually, while the hill lands are devoted to grain, cowpeas and cotton. The area in timber varies from one-third to two-thirds of a farm, according to location. The farms near the cities are nearly all in cultivation. The pastures, as a rule, are sufficiently large, but inferior as to the quantity of grass, as the majority of the farmers depend entirely on native grasses. These farmers have modern cottage homes, painted and neatly kept, commodious barns and plenty of farm machinery. It is not uncommon on such farms to find gasoline engines to pump the water and to cut the wood and feed, grain drills, reapers and mowers, disc plows, harrows and weeders. These

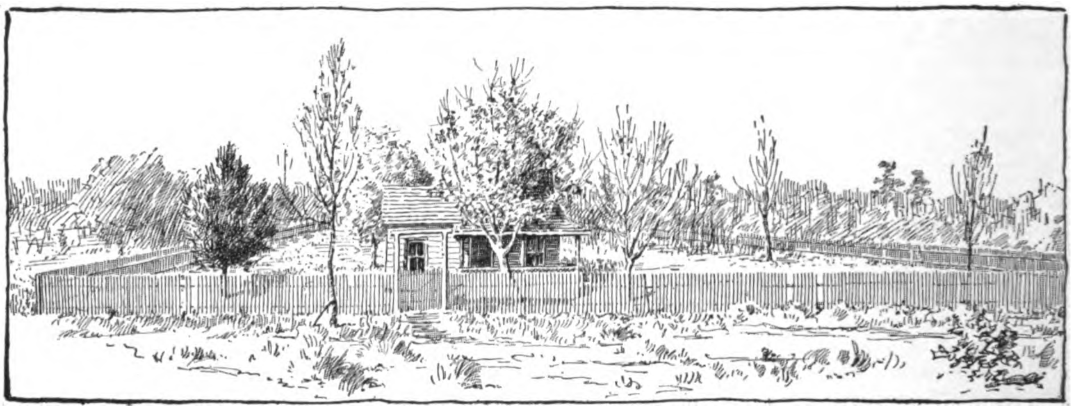


Fig. 163. A small poor farm in northern Florida, fenced off in the woods. Such units are too small for effective agriculture on poor lands remote from market.

farmers are progressing, improving the soil and increasing the yield. Where formerly half a bale of cotton, twenty bushels of corn and ten bushels of wheat per acre were considered good crops, by thorough cultivation and a liberal use of fertilizers, farmers are now raising two bales of cotton, eighty bushels of corn and forty bushels of wheat. Last year (1905) the writer saw lands that yielded two hundred and one and one-half bushels of corn, three bales of cotton, and sixty-one bushels of wheat per acre. This, of course, is exceptional. There is no doubt that for the average southern farmer, far removed from the cities, this combination forms the ideal system of farming.

A more systematic layout of the farming lands is needed. The fields are generally irregular in shape and area, and do not present a pleasing appearance or offer the greatest saving in time or space. There is lacking that definite plan which would add greatly to the ease of administration and the value of the farms.

Dairy and stock farms.

Dairy and stock farms are springing up rapidly in the South, and many are being equipped with the very best strains of stock and all the up-to-date appliances. The increased population of the cities and the building of many cotton mills and manufacturing plants have greatly enlarged the markets for all dairy products. When intelligently managed, these dairies are prosperous. Many farms have well-equipped dairy buildings and barns, and the majority have silos. The southern farm can grow as much corn per acre as any other section, and fill the silos as cheaply. The great drawback is the fact that the farmers have not learned to grow enough grain, nor have they been in the business long enough to get the lands sufficiently fertile to produce large yields, as is done in the North. The dairymen are buying much of their concentrated food instead of producing it. Since the lands will produce two crops annually, wheat or oats followed by corn, peas or sorghum, there can be no excuse for not growing all the food supply.

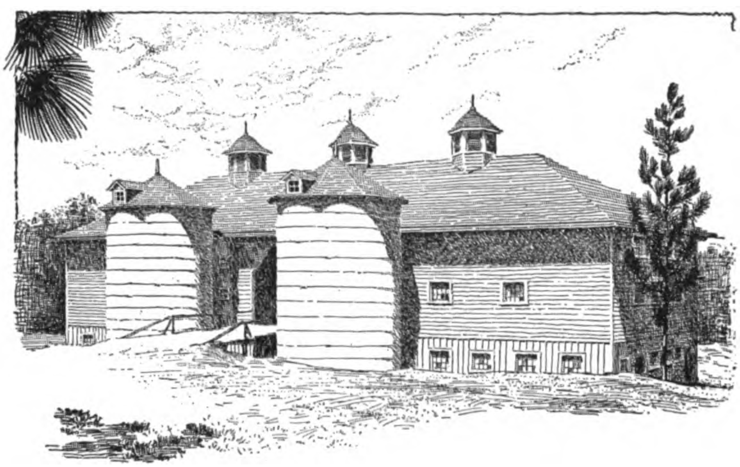


Fig. 164. One of the better type of southern stock barns.—On the farm of J. M. Givens, Aiken, South Carolina.

Some dairymen rely on pasturage to a great extent, and, as lands are cheap, they have large pastures. Others rely on soiling and have only small pastures for exercise and water. The Bermuda-grass cannot be excelled as a pasture-grass, and will furnish grazing for nine months in the year, while by the addition of bur clover and rye cows could be pastured for twelve months. Within the last twelve months many well-equipped creameries have been built in the cities. These will be a great stimulus to the dairy industry, as they will offer ready markets for the milk.

The stock farms, as a rule, are not so successful, except in the case of hog-farms. In the sandy sections the hogs are fattened on peanuts; in the

Fig. 165. Typical Georgia farmhouse of the diversified farmer. Cotton is often grown up to the very doors of the houses.

hilly sections they are fed on rape, alfalfa, sorghum, peas and potatoes, and finished on corn. It is not uncommon to raise them to weigh three hundred pounds or more at one year old. As to horses, beef-cattle and sheep, the southern farmer has not learned to handle them or raise them to advantage. The New South has not yet had time to develop a supply of capable stockmen. The sheep industry is being revived, and it is hoped that the proper attention will be bestowed also on horses and beef-cattle.

Trucking.

This line of farming has received a great impetus within the last few years through the influence of better home-markets and increased shipping facilities. The truck-farms vary in extent from ten acres to several hundred. Around the cities many farmers are contenting themselves with small areas and are practicing the intensive system to advantage. Every southern state has sections in which numerous farms are devoted to truck alone. Berries, cantaloupes, watermelons, lettuce, radishes and the like are grown for northern markets. Near the cities, where truck is grown for the local markets, every variety of vegetable is produced. Fair yields are obtained by many of the truckers, though but few can equal the northern truckers, who have been much longer in the business. The writer has known of over three hundred dollars' worth of raspberries and strawberries to be sold from an acre, seven hundred dollars' worth of spinach, and eight hundred dollars' worth of cabbage. Some truckers are putting in irrigation plants, and many are building well-equipped hothouses and fitting themselves much better for their work. In the mild southern climate the coldframes answer the purpose of hothouses for all ordinary needs and are in general use.

Fruit orchards.

In peach-growing the South has outstripped all other sections within the last few years. This is largely due to the Elberta peach, the fine appearance and shipping qualities of which have led many persons to put out commercial orchards. The profits have been such as to enlist men of all classes and professions as fruit- or peach-growers. In this kind of farming Georgia leads all other southern states, having many millions of Elberta peach trees. The growers are nearly all planting earlier and later varieties, so as to prolong the shipping season and not to have all the fruit marketable at one time. This crop has now reached a total output of 5,000 cars, and orchards are still being set out, varying in size from fifty to one thousand acres. It is found that the pebbly lands are adapted to peach-growing, and especially the hills, where the danger from frost is lessened. These orchards exhibit a more systematic layout than any other kinds of farms, and usually present a beautiful appearance during the spring and summer. The peach trees are set fifteen to seventeen feet apart each way, and are pruned so as to branch near the ground, and have a regular umbrella shape. Most of the fruits can be gathered by a person standing on the ground.

The apple has begun to receive attention and within the next five years will be developed greatly, and promises to keep pace with the peach. Canneries are now receiving due attention. These are being established in all fruit centers. The pear is almost neglected because of the serious ravages of the blight. Plums are beginning to receive attention, especially the new large varieties.

Suggested subdivision of a mixed husbandry farm for the South.

As the lands were originally surveyed into lots of two hundred acres, this would constitute the most convenient size of the average farm. The dwelling-house should be located according to road facilities, but as near the center of the frontage as a suitable site would permit. Two acres should be devoted to this site for the buildings, shade-trees and flowers. The dwelling should be a modern six-room cottage, with ample porches on at least two sides to furnish shade and coolness in summer. The barn and lot should be at least two hundred yards in the rear and sufficiently large to house four horses and twenty head of cattle. An acre may be devoted to this and other outbuildings, such as shelters, hog-pen, and so on. An ample tool- and manure-shed should be one of the features. Two good servant-houses should be built on the edge of pasture or woods lot, according to convenience. A lane should lead back to a twenty-acre pasture, the location of which should be decided by the water-supply, the lay of the land, and the type of farming. This pasture should be enclosed with the best woven wire fence and well-set in Bermuda-grass, which is the blue-grass of the South. All the cattle and the hogs could range together. At least three good brood-sows and a thoroughbred boar should be kept; also five Jersey cows and five of the beef type; two strong mares and a pair of heavy mules. The chickens should be given free range. One acre, well-enclosed, should be devoted to a kitchen-garden, and three acres given to orchard purposes. Five acres near the barn should be devoted to potatoes, alfalfa, sorghum, and the millets to furnish ample green food and additional forage. There should be twenty acres for hay land, and twenty-eight acres left in timber for wood and posts. This would make eighty acres, and would leave one hundred and twenty to be divided into three equal fields, to be rotated in cotton, corn and grain, the grain to be followed by peas. Such a system would give with intelligent husbandry the following approximate returns, besides the home supplies:

40 bales cotton at $50	$2,000 00
3 milk cows at $50	150 00
7 head beef cattle at $40	280 00
Butter and meat	150 00
Chickens, fruit and potatoes	100 00
	$2,680 00

Such a system of farming would accomplish five very desirable objects: (1) It would give cash for proper maintenance of the family; (2) insure abundance of food for the farm; (3) preserve and increase the fertility of the soil; (4) reduce the commercial fertilizer bill; (5) prevent the land from washing.

LAYOUT OF THE CORN-BELT FARM

By *G. W. Hervey*

The layout and organization of a farm in the geographical region represented by the Missouri valley country, has received by example, in squares and right angles, an inheritance from the United States government surveys that was adopted by the pioneer homesteaders in the early settlement of the country in the laying out of their farms, and has been brought down to the present time with marked unanimity in form and style. The corn-belt farm carries out the original idea of square tracts of land or tracts with uniform boundaries, such as are described by sections or fractional parts of sections.

The corn-belt farm has become a farm of mixed husbandry on which all branches of agricultural production, live-stock-raising and kindred interests are conducted, thus necessitating a studied and methodical subdivision to serve best the purposes of pasture, meadow and cultivated crops. The most generally accepted subdivisions for the convenience of crop and pasturage purposes, are the ten-, twenty- and forty-acre enclosures. At least two of these should be pastures directly accessible from the barnyard or feeding enclosures, which may be grouped with farm buildings and improvements and described more fully in that connection.

Subdivisions.

For best average results in conducting a properly balanced farm industry, the one-hundred-and-sixty-acre farm may be apportioned in crop as follows: forty acres to corn, forty acres to meadow, forty acres to pasture, thirty acres to small grains. These may be subdivided to suit the convenience of existing enclosures. The twenty-acre enclosure, however, on the one-hundred-and-sixty-acre farm is handled to much better advantage in crop-rotation than larger divisions. One of the

Plate X. Farm lands in eastern Nebraska

main features of importance in laying out the farm into fields of convenient size for crop cultivation is the advantage of fertilizing the cultivated lands used in the growing of corn and small grains, by giving them a period of recuperation in the production of leguminous crops, such as clovers, alfalfa and the like.

All the features of subdivision on the farm are directed, in matter of convenience, toward one common center, where are gathered, for storage and feeding advantage, all crops produced on the farm. This headquarters represents the home and base of operations for directing the entire operating force of the farm.

The residence is made the greatest feature of decorative skill and architectural beauty to be found on the farm. It should be large, roomy and attractive, and control a space for lawn and ornamental grounds of not less than one acre, preferably situated on slight elevation sites. Location for buildings must be governed by sites and exposures affording good natural drainage and dryness of soil. When these are secured, the greatest advantage is had in a location near the public highway and central on the line of the road extending through or by the farm. This gives a larger acreage near the farm buildings, and aids in convenience of fencing to secure more direct access to the remote enclosures, where crops are raised or stock pastured.

Back of the residence lot is the natural location for the family orchard of approximately three acres, containing as complete an assortment as possible of the fruits adapted to the needs of the family. In conjunction with this is one acre in separate enclosure devoted to small-fruits and vegetable-garden. One-half acre adjoining the orchard and opening into it, should be suitably fenced and furnished with modern buildings for handling the farm poultry. One acre is needed for barnyard, one-half acre for stacks and four acres for feed-yards and stock-lots, divided to suit the convenience of the cattle, swine, sheep and such other stock as may be kept on the farm.

From the beginning of settlement on the naturally treeless prairie of the corn-belt country, tree cultivation and forestry improvement have been matters of great interest to the landowner. At the present advanced stage of improvement, the grove of a few acres, with the tree lines and shade trees planted about the stock-lots and farm buildings, marks one of the most attractive and cheerful features of farm-home improvement.

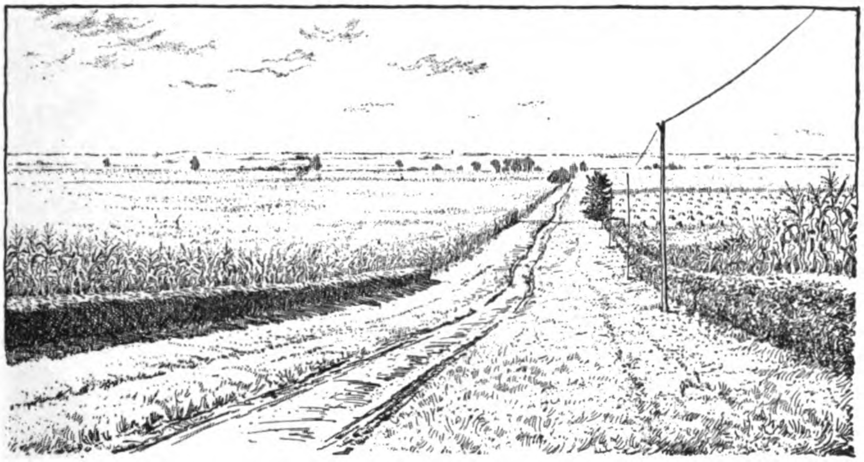


Fig. 166. Farm view in the Illinois part of the corn-belt, showing the great sweep of fields. A field of 160 acres of corn on the left.

Roads and fences.

The fencing and laying out of roads on the farm are made to conform to the subdivisions as planned and plotted for their various purposes, in crops and pasturage advantages. These should be made features of permanency in the layout of the farm, and so recognized in its economical conduct and management. All fences on the farm are to be substantially and solidly built. The barbed-wire fence is the common, every-day, cheap and serviceable farm fence, and is the one in common use on the average corn-belt estate for the general farm fence enclosure. The four-strand barbed-wire fence, with posts set sixteen feet apart, is a satisfactory cattle and horse fence. For hog and sheep pastures the woven-wire fence has come into general use, and its presence around a pasture suggests a feeling of pride, expressed by the hackneyed expression "hog-tight." The alfalfa or clover hog-pasture has become as much a part of swine industry improvement of the present day as the bare hog-lot is a reminiscence of former times.

All roads on the farm are made to have their base of survey from the barnyard, and are laid out near to and parallel with the fence leading to the most remote fields on the farm. In no case should a road angle across an enclosure, but continue in a direct line along the fence enclosing the field to an opening at the corner leading to other enclosures. By this system of farm roads, with gates at the corners, a complete circuit may be made of the farm at any time of the year along its laid-out roads, passing from one enclosure to another without interference or damage to crops. Section lines being legally established public highways, when once opened, offer opportunity for approach to fields and enclosures that the well-planned farm, with its buildings and improvements properly located, may utilize to great advantage.

Barns and yards.

The plan of the barnyard, with its buildings, stock-lots, feed-yards, watering fixtures and appliances for the successful and economical management and handling of the farm animals, is a matter of vital importance to the farmer. Inasmuch as the element of profit or loss is introduced at this juncture, it becomes very important that a proper and correct foundation be laid in the establishing of the stock-lot and feed-yard system of the live-stock industry of the farm. Comfortable, roomy sheds and stock-barns must be provided for all stock. These should be made to open out into spacious yards or lots well-protected by proper drainage to carry off all surface waters, and be supplied with the best modern appliances for keeping pure and clean everything in the way of feed and drink intended for the animals. Feed platforms made of two-inch plank, closely jointed and set on an elevation slightly above the surrounding surface, when kept clean by scraping and sweeping, offer the best advantages for the hog-lot when self-feeders are not employed.

Sanitary possibilities are the first matters of consideration in the selection and layout of the barnyard and stock-lots. The barnyard should not be a stock-lot nor considered as one, other than its proximity to the stock-lots and its advantage for opening into them, as a matter of convenience.

Since mixed husbandry has become so fully established on the farms throughout the corn-belt country, introducing every feature of live-stock enterprise and industry from the breeding of pure-bred stock to the finishing of the range steer for the beef market, there has been a gradual demand for feed-lot improvement. The old-time muddy hog-lot has been supplanted by the dry yard and the alfalfa pasture. The feed-lot for the steers has been tiled and drained to carry off as much of the surface water as possible. The open feed-lot with a tight board fence on the northern and western sides or an open south and east front shed has taken the place of the two extremes,—the wire fence and the closed shed or stable.

The water-supply is only second in importance to the feed-supply. The usual system employed in securing the farm supply of water is from wells, lifted by the aid of pump and wind-power. The well is located on an elevation above the point of discharge, and from a large supply tank or reservoir the water is piped, under ground, to supply tanks in the various divisions, barns or enclosures where it is to be used. This system of water-supply, when properly guarded, is the cleanest and least liable to contamination of any in use. The well is fenced and every precaution used to keep stock from it, or prevent any drainage or seepage collecting near it. The same system is observed in supplying water to pastures and other parts of the farm demanding water.

Cribs, granaries and storage houses for all the grains and feeds produced on the farm are quite as important a part of the farm economy as the system of cultivation in the production of the crops. It matters not how much is produced; if it is not carefully harvested and properly taken care of, it results in loss to the farm industry. The double crib (Fig 167), with driveway between, is coming

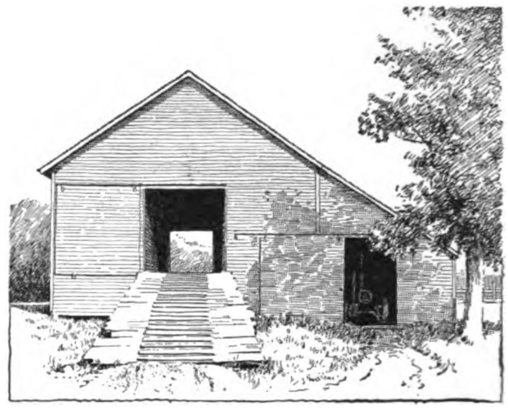


Fig. 167. Corn-house in the western corn-belt.

more into use as the farm crib, since it may be utilized as a wagon-shed and for driving loads under in case of emergency, to protect them from rain or storm. The crib room should be one-half more than the average annual yield of the farm. This is to allow for corn that is being carried over unfed, or the laying in of corn when the prices and the feeding demand may seem to warrant it.

Granaries for the small grains are preferably separate buildings, and are now usually so constructed. This granary is also planned to exceed the storage requirements of the average crop, in order to meet the demands of exceptional seasons in acreage or yield. Some persons also prefer that the horse-barn be separate and apart from other structures, though it is very frequently made a part of the main barn.

The storage of hay in barns is not regarded as of any particular advantage, unless there is a feeding demand in the barn for the hay. Stacking hay is the common and popular method of storage for this crop, and the stacking-lot alongside the feed-yard is estimated both as a wind-break protection and as a saving in the labor of feeding out the hay. Outside hay-racks or cribs with capacity for holding large quantities of hay are also very generally in use in the feed-yards and stock-lots for all classes of cattle. These are supplied by hauling direct from the haystacks in the meadows a supply that will last for several days.

Rotations.

Crop-rotation and maintenance of soil fertility are subjects now beginning to command attention on the corn-belt farms. Results of experiments in the plowing under of leguminous crops, grass sods and the spreading of barnyard manures and refuse gathered from the stock-lots, have demonstrated the value and need of increased fertility in crop production.

The western corn-belt farmer rotates corn with small grain in order to get the land in suitable condition of tilth for clover or alfalfa, the crops best suited for restoring nitrogen to the soil. The demand thus created for alfalfa and clover seed has been a potent factor in creating prices higher than ever before known. The tendency among the best farmers is to grow more alfalfa in order to be able to grow more corn and wheat. The self-fertilizing properties of this crop, in their value to the common grain crops of the farm, are just beginning to be made use of in practical agricultural work. Likewise is the husbanding of the farm manures becoming a feature in the economical management of the corn-belt farm.

LAYOUT OF A LIVE-STOCK FARM FOR THE MID-COUNTRY

By *Frederick B. Mumford*

The mid-country embraces those states in the Mississippi valley which lie almost in the exact geographical center of the United States. This region is more frequently called the middle west. It is in the center of the corn-belt.

In considering the operation and management of a mid-country farm, it will be important to have a clear knowledge of some fundamental principles of administration, which may be widely applicable to farming operations in general. It must be understood that this discussion has reference to the typical mid-country stock-farm, and will therefore necessarily eliminate any reference to vegetable- or fruit-growing, chicken-farming, squab production, ginseng plantations or mushroom caves, all of which may be conducted successfully on small areas. The mid-country farm is distinctively a grain and live-stock producing area. This type of farming requires much larger areas than most of the so-called intensive systems of agriculture, and it is conducted on an entirely different basis. The administration of these larger areas has produced a system of extensive agriculture which has had a most profound influence on the social and economic development of the farmer himself.

The management of large farms requires business ability and leadership. The handling of large numbers of men and teams and the care of complicated modern farm machinery have resulted in developing generalship to a marked degree. Not only have the highly favorable circumstances of fertile soil and equable climate drawn able men to agricultural pursuits, but the very limitations placed on his operations by scarcity of labor, distance from markets and difficult transportation, have resulted in an extensive system of agriculture that is highly profitable and attractive to men of ability and training. Under this system the profit per unit of production, as per bushel or per animal, is often smaller than under more intensive systems, and thus from necessity the farmer has been compelled to produce a larger number of bushels or of animals. To do this required more land and labor-saving machinery. This machinery has revolutionized modern agriculture and forever lifted from the tiller of the soil the excessive burden of hand labor, which, under European conditions, has crushed ambition, destroyed intellect, and by a process of natural selection driven the brightest minds away from the land.

The type of farming in the mid-country, therefore, is general agriculture (grain- and stock-farming), tending more and more to live-stock production. The growing of grain exclusively for sale over wide areas is practically past. The typical mid-country farm is now distinctively a stock-farm.

Size of the farm.

There is a lower limit to the number of acres which may be profitably administered by one man. It requires but little larger outlay for machinery on a 240 acre farm than for one comprising 80 acres. The buildings and fences cost much less per acre on a large farm. One man should be able to manage the larger area as easily and at the same time derive a greater profit. The smaller area may be so operated as to yield a larger return per acre; but in the administration of a stock-farm there is no fundamental reason for greater profit per acre from the smaller area. On the other hand, the economic advantage of purchasing and selling live-stock in car-load lots and of employing perfected labor-saving machinery, are all in favor of the larger farm. In the writer's opinion, a stock-farm in the mid-country should comprise at least 160 acres, or, better still, 240 acres. It is possible to increase the size of the stock-farm indefinitely, but the profit per acre will, in general, decrease as the area increases beyond 240 acres.

Let us assume, then, a 240-acre farm in the middle west to be operated as a stock-farm for profit. This account describes an actual farm with fences, buildings and other improvements as now in active use.

Field divisions.

The diagram (Fig. 168) shows the arrangement and size of fields, location of buildings, roads, orchard, water system and wood-lot. This arrangement of fields is nearly ideal. The buildings are as near the center of the farm as possible and connected with every field, either by a public or a private road. It is not desirable to have smaller field divisions than here shown, as the first cost and maintenance of fences is a very considerable item.

The windmill at the house (Fig. 169) furnishes water from a deep well for the family. The water is carried to the fields and barn by pipes, being accessible to every field by means of the farm road. The roadsides are planted with sugar maples and groups of trees surround the homestead.

Cropping plan.

The profits will depend largely on the amount of production and the cost per bushel, per animal, or per unit of production. The net profits may therefore be increased by increasing the yields per acre and by decreasing the cost of growing, handling and marketing.

As the first factor depends primarily on soil fertility, the problem of increasing or at least maintaining fertility must be considered in deciding on a cropping plan. The second factor calls for executive ability and involves the labor of men

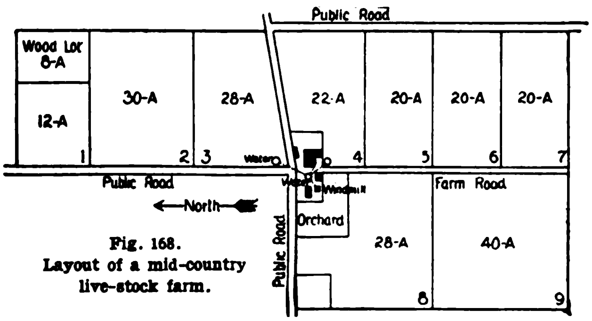


Fig. 168.
Layout of a mid-country live-stock farm.

and horses, and the use of labor-saving implements. The foundation of all successful farming in the middle west is now and must ever be the skillful growing and handling of Indian corn. The other crops are grown largely as supplements, or are employed for the purpose of aiding in maintaining fertility. There are several successful rotations with corn as the mainstay. One rotation is corn followed by a small grain (either wheat, rye or oats) and this by clover. This is a common three-year rotation and is always successful when clover can be seeded on small grain in the spring. On a farm of 240 acres devoted chiefly to the production of live-stock, a good cropping plan for each year would be sixty acres of corn, sixty of wheat, rye or oats, sixty of clover and sixty of permanent pasture. This simple plan, combined with the careful application of all barnyard manures, is one of the most profitable yet devised. It is always easy to modify this general plan to provide for the planting of special crops, such as rape for pasture, sorghum for winter forage, or cowpeas on particularly poor spots where clover fails to grow.

It is always advisable, however, to plant the full acreage of corn and clover each year, decreasing the area of small grains to provide for the special crops.

Some of the modifications of the above rotation that are particularly adapted to the stock-farm are the following: (*a*) Early in the spring, sow one bushel of oats and four pounds of Dwarf Essex rape per acre on well-prepared land. This mixture will yield a very abundant and highly nutritious pasturage that may be utilized for all classes of live-stock, but is especially profitable when fed to fattening sheep or hogs. (*b*) Sow sorghum with a grain drill at the rate of one-half bushel per acre. This may be sown as late as July 1, but is best sown from June 1 to 15. This makes a coarse hay that is cut with a mower and is cured as hay and finally raked and forked into small ricks containing about one thousand pounds each and left in the field. If placed in larger permanent ricks, it frequently moulds and is seriously injured for feed. (*c*) Grow corn in drills planted somewhat more thickly than for the ordinary crop, and turn in the fattening hogs or sheep and allow them to harvest the crop.

Utilization of grain and forage.

A permanently prosperous agriculture demands that every bushel of grain, or, if sold, its equivalent in purchased foods, should be fed on the farm. This is also true of the hay.

Following the rotation advised above, there will be produced annually on a good farm of 240 acres approximately the following: 3000 bushels of corn, 1200 bushels of wheat or rye, or, in place of these, 2500 bushels of oats, 90 tons of hay, and pasturage for 30 head of cattle and horses, or their equivalent in other stock. The profitable utilization of this large amount of grain and forage is sometimes a difficult problem. It is not possible to give one definite plan that will be best under all circumstances. The changing markets for breeding animals, fat stock and work or pleasure animals will necessitate changes in the general plan. The following general considerations will be useful, however, in determining a profitable plan. (*a*) A safe method is to produce, by breeding, lambs, young cattle, hogs and horses and finish these for the market by employing the feeds grown on the farm. (*b*) Another plan, more common in the corn-belt in former years than now, is the fattening of cattle, hogs and sheep that have been purchased in thin condition, direct from the producers or from the great live-stock markets. This latter plan is open to the objection that it is always a speculative venture and may or may not prove profitable.

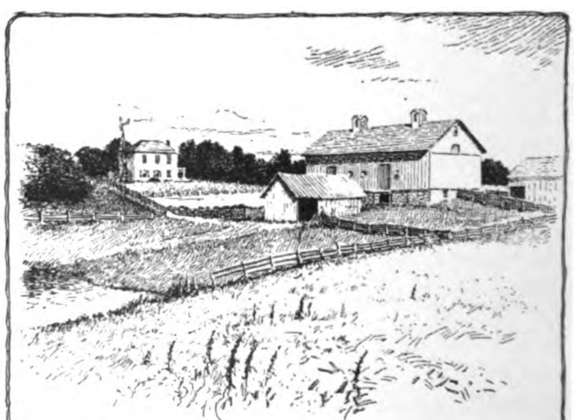


Fig. 169. Administration area of the Montford farms, shown in Fig. 168.

Either of the above plans involves a knowledge of the art of feeding animals, and of their relative efficiency in producing meat from the grains and forage. In general, it may be said that it requires an equivalent of ten pounds of corn, with roughage, to produce one pound of beef, and five pounds of corn, with roughage, to produce one pound of mutton. Hogs are still more efficient and on the average will return one pound of pork for every four and one-half or five pounds of grain. Moreover, fattening hogs require so small a proportion of roughage that we may ignore this item entirely in the above comparison. When roughage in the form of clover or other pasture is employed for hogs, less grain than that indicated above will be required. It is not ordinarily wise for the general farmer to produce only one kind of animal. While hogs are undoubtedly one of the most profitable animals, they can not be depended on to utilize roughage in the form of hay or straw, and only a comparatively small amount of pasture.

Equipment for a 240-acre farm.

A well-managed farm of the above size should carry the following equipment of live-stock: A flock of two hundred breeding ewes, fifteen brood sows, five cows and six work-horses, at least four of which should be heavy mares capable of producing good draft colts or mules. The young stock should all be fattened before selling. The annual sales from such a farm, barring disease, accident or unusually bad crops, would be approximately the following: Fifteen hundred pounds of wool, two hundred fat lambs, one hundred and ten fat hogs, weighing two hundred pounds each, five fat yearling cattle, weighing nine to eleven hundred pounds each, and four draft colts. There should also be sales of eggs, poultry and butter amounting to a considerable item. In addition, if the above cropping plan is followed, there will be for sale annually 1,000 bushels of wheat. The plan here contemplated, however, involves the purchase of concentrated foods, as cottonseed meal or linseed meal, of a value not exceeding the sales of wheat.

The progressive and successful farmer must have the best labor-saving machinery. It economizes labor and insures saving the crops when labor cannot be secured at any price. The expense of such machinery is large, but is justified on a farm of the size here contemplated. The machinery should include one gang plow (two fourteen-inch plows), one walking plow, one four-horse disc harrow, one smoothing harrow, two corn cultivators, one grain drill, one self-binder, one corn binder, one mowing-machine, one side delivery rake, one hay loader, one hay fork with pulleys and rope, one farm wagon, one low-down platform wagon, and small tools, as forks, shovels, hoes and so forth.

Summary.

The most important general principles that govern the above system are: farm sales exclusively of animal products, thus conserving soil fertility; extensive use of labor-saving machinery and of horse power instead of hand labor; producing the animals on the farm and finishing them with the products grown on the same farm; handling carload lots; continuous large areas of corn and clover, and a definite area of permanent pasture.

THE LAYOUT OF A FARM IN AN ARID REGION

By *W. M. Jardine*

The methods of farming in an arid region show considerable variation within the same section of the country; and of course a very great difference obtains between the methods employed there and in a humid region. When it is remembered that the word arid means dry, sun-scorched, destitute of moisture as opposed to the moist, damp atmosphere of humid regions, it is not difficult to conceive of the vast difference in the treatment required for crops.

A region is considered arid when the total annual precipitation is fifteen inches or less. Time and experience have demonstrated that in such localities farming cannot be practiced successfully without artificial application or conservation of water. This, then, is the vital, fundamental consideration in farming arid lands, namely, the storing, by scientific methods, of all precipitation, and the effective utilizing of this on the land under cultivation. In many instances, communities resort to the storage reservoir or the mountain streams for their supply, and this constitutes simple irrigation.

There are three main types of farming in an arid region: (1) by means of irrigation; (2) by so-called "dry-farming"; (3) by ranging. These types may be briefly discussed with reference to the layout of the farm area. It is not intended to enter into any discussion of the methods and special practices of these types of agriculture.

Layout of an irrigated farm.

In Fig. 170 is shown the layout of an eighty-acre irrigated farm. The water enters the field at the northwest corner. The main irrigating ditch continues along the east side, two parallel laterals intersecting it at right angles. One of these laterals extends along the north side; the other crosses the center of the field. With such a system, it is possible to distribute the water equally over the field with the least number of ditches. It is important that the slope of the surface be smooth and uniform. The best possible grade will vary considerably with the character of the soil. One to three feet drop per hundred feet will probably be the most effective. When the field is laid out properly, as in Fig. 170, very little labor will be necessary in distributing the water. This plan can be considered as representative of an irrigated farm, particularly as regards the scheme by which it is divided into lots and planted to satisfy the requirements of rotation, and to enable the farmer to distribute his work throughout the year to the best possible advantage.

The annual crop harvested from such a farm should be about as follows: Ten acres of orchard should average about $150 per acre; twenty acres of alfalfa, at the rate of six tons per acre, $4.50 per ton; five acres of wheat, at sixty bushels per acre, seventy-five cents per bushel; twenty acres of sugar-beets, at twenty-five tons per acre, $4.50 per ton; five acres of oats, at eighty-five bushels per acre, forty cents per bushel; potatoes at the rate of 300 to 500 bushels per acre, thirty cents per bushel, and other miscellaneous crops comparatively high. In some parts of the arid country yields and prices are higher.

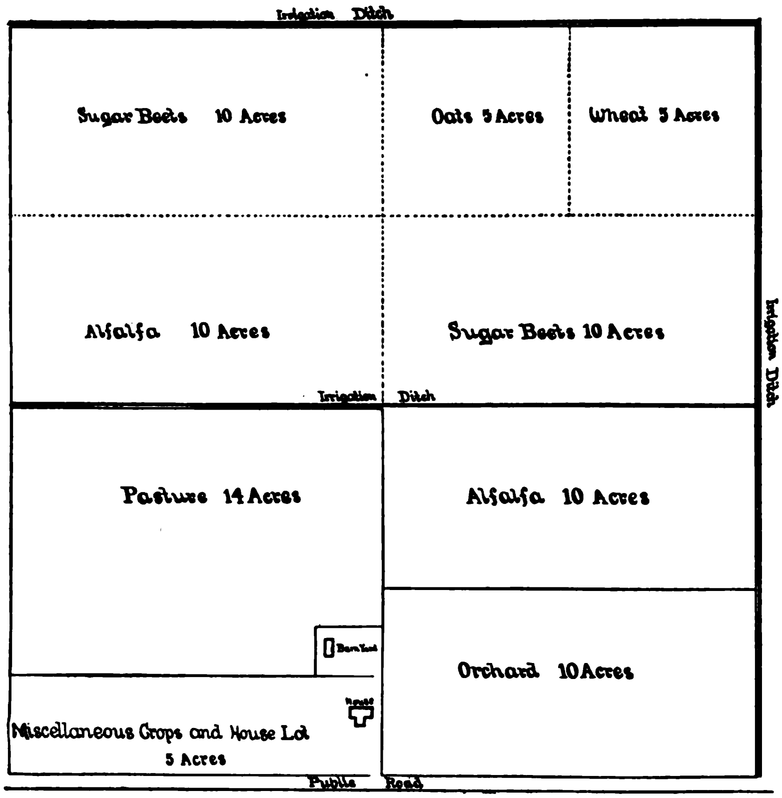


Fig. 170. Plan of irrigated farm in the arid region.

An eighty-acre farm in Utah, Colorado, Idaho or Montana, would possibly incur a greater expense in its operation than would a 320-acre farm in Iowa, Michigan or Wisconsin. When men work the entire year they are paid $25 to $40 per month, according to the man. Day-laborers demand $1.50 to $2 per day. Since there is work enough on the farm described to keep two men busy throughout the year and additional help during the harvesting season, July, August, September and October, the annual expense for labor will approximate $1,200. The farmer estimates that his dairy products, marketable animals, wheat, oats and miscellaneous crops will yield cash sufficient to cover the entire expense incurred in running the farm. This leaves, as clear gain, the entire orchard and sugar-beet crop, giving a net profit which may be estimated at not less than $3,000.

It will be seen from these results that, with irrigation in an arid climate, where the soils are among the best in the world, and the sun hot dry and scorching, it is possible to do farming of the most intensive kind. It is no longer a question of land, but rather of water. In other words, it is $10-acre land and $100-acre water. This makes intensive farming necessary if the greatest possible profit is to be realized from a water-right. As a result, the expense is correspondingly high and becomes an item of first importance.

The fact that the supply of water is so limited as compared with the immense tracts of land that might otherwise be brought under irrigation raises at once the vital question of its economic distribution. When the farmer knows that every acre that can be irrigated is to increase in value a hundred-fold, he exerts himself to the utmost to realize the greatest utility of water.

There are two methods of applying water,—the flooding method and the furrow method, either of which is equally good so far as present investigations indicate, varying only with the difference in character of soil, crops or local conditions. In the first, or flooding method, the water is allowed completely to cover the land, the extent to which a field can be flooded depending on the levelness of the surface. This is the method used on the large farms, especially on the alfalfa fields. The second, or furrow method, is used when the land has been run over with a marker, making shallow furrows or rows, twelve to eighteen inches apart, through which the water can pass nearly unobstructed. This method is practiced to a considerable extent on grain-fields, but very seldom in an alfalfa field.

The methods of maturing and handling the farm crops in an arid region vary little from those employed in a humid section, except, possibly, in the case of alfalfa. Two to four cuttings of alfalfa are taken from the land during the year. For this and other forage crops silos are seldom used, since the crops can be cured easily on the field.

Up to the present time, very little attention has been given to the rotation of crops, owing to the fact that arid soils are usually very fertile, and as yet they are comparatively virgin. Progressive farmers, however, are beginning to adopt a system of rotation. On the farm described, or a typical farm of this region, the rotation would be about as follows: wheat, sugar-beets, sugar-beets, wheat and alfalfa. This rotation might be four, five or more years with these same crops, but whenever sugar-beets follow themselves barnyard manure is applied to the land, not particularly to add fertility but rather to improve the physical texture of the soil.

The "dry farm."

Although it is considered that irrigation forms the basis of agriculture in an arid region, yet it is estimated that less than two per cent of the arid lands are under irrigation, and it is further estimated that after the art of storing and applying water has been perfected, there will still be insufficient water to irrigate ten per cent of the total area. Recent investigations of dry-farming, or farming without irrigation, have demonstrated that paying crops can be produced in regions where the annual precipitation is as low as ten inches, thus bringing under cultivation millions of acres which up to the present time have been considered useless, except for range purposes. [See page 398.]

A typical dry farm would be about 320 acres, devoted almost exclusively to the growing of drought-resisting crops, such as wheat, oats, barley, rye, native grasses, alfalfa, and the like. Such farms are usually divided into two main fields of 150 acres. One field is summer-fallowed while the other is producing a crop. In this way, one-half the land is lying over every year in order to store up two years' moisture to produce a crop. The main product of a dry farm is wheat, other crops being grown principally for feed. Fall-plowing is practiced whenever possible, so that the soil will be in better condition to hold the moisture from the winter snows and early spring rains. The plowed ground is cultivated during the summer with an ordinary disc harrow or smoothing harrow, the purpose being to hold moisture in the soil and prevent the growth of weeds. The average yield of wheat per acre is about fifteen bushels. Very seldom is one of these farms inhabited the year round. The owners usually have a few acres with a water-right where they live in the winter months, and on which sufficient hay is raised to feed a few head of animals. This kind of farming will always be one of the leading phases of agriculture in an arid region.

This kind of farming has been practiced for many years, but it is only since 1904 that the system has developed into a profitable industry. Thousands of bushels of wheat, barley and oats are being produced on land that five years ago was thought to be less than worthless, and as yet this method of farming is but in a primitive state. The system adopted and followed by the most successful farmers is one that will admit of the operation of large tracts of land at a minimum expense. The importance of such a system will be appreciated when we consider the gross receipts of one acre. With an average yield of 15 bushels of wheat worth not to exceed $10, it is evident that all farm operations must be done on an extensive scale in order to be profitable. To do this, especially adapted machinery must be used, machinery that will enable one man to handle many acres of land in a single day. On the larger farms, steam power is taking the place of horse power to a great exent. When it is the object of the farmer to grow dry farm crops only, it becomes necessary, and is the custom, to increase holdings to 640 acres or more.

In dry-farming the practice of rotating crops with any system is practically unobserved, unless it is among a few of the most successful farmers. The following plan illustrates common practice:

1. Wheat; summer fallow; wheat.
2. Wheat; summer fallow; oats; wheat.

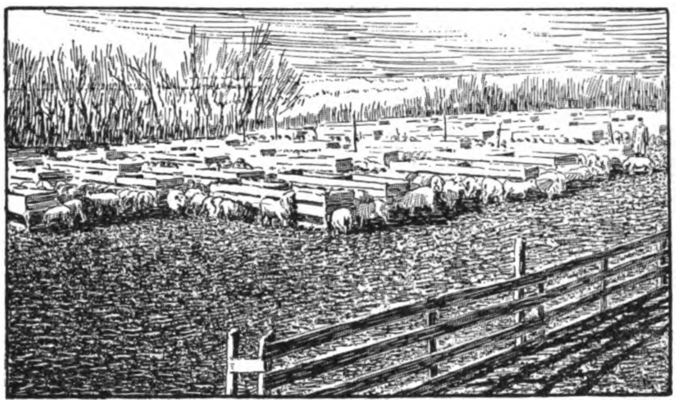


Fig. 171. **Sheep-pens, for feeding range stock, in the farther West.**

A system of cropping that would answer the requirements of a rotation for the dry lands would be about as follows:

Wheat; field-peas; wheat; corn or potatoes; barley or oats; alfalfa for a series of years.

With such a rotation a permanent agriculture could be established for the unirrigated lands of the far West.

The range.

Aside from the irrigation and dry-farming of the West, the "range" should also be mentioned. The range is the open, unfenced country, typically that belonging to the government, on which stock is pastured in large flocks or herds. Range-farming is dependent to a considerable extent on irrigation-farming. The open range no longer provides sufficient pasturage for the flocks and herds during the entire year. Three months of the year, during the most severe winter weather, all live-stock must be fed, except in a very few localities; hence it is that range-farming becomes dependent on irrigation.

The range stock is usually shipped from the range directly to eastern buyers, but a better practice, and one that is becoming recognized as such by the stock-growers, is to finish the animals on the alfalfa and grain produced in the West before final sales are made to the eastern markets.

Range-farming in the past has been poorly organized, and is so yet; but since the national government began the establishment of forest reserves through the entire West, a gradual change for the better is becoming evident, and the present indications point to a better organized system.

CHAPTER V

THE CAPITAL REQUIRED IN FARM OPERATIONS

FOR THE GREATEST EFFICIENCY as a business and economic enterprise, the average farm is no doubt under-equipped and under-supplied with moving capital; or at least it is not so equipped as best to adapt it to its particular conditions. The farmer, in such cases, is not able to make the most of his original land investment and of his commercial opportunities. There must be some proportionate relation between the first or foundation investment, the working capital and the extent of equipment.

In the past, the farmer was not able to make the most of human labor, and farming was menial. In proportion as labor is cheap, meniality is likely to persist, with consequent social stratification. As labor increases in price, it is economized and made more effective by better organization and by equipment that will utilize it to the full and multiply it. The great development of machinery in the Middle West of the United States, for example, is a means of making human labor effective. Whatever develops farming out of meniality raises it into the plane of managership: herein lies the fundamental demarcation between poor farming and good farming. The proportion of working capital to original investment is likely greatly to increase, and this will influence the labor problem.

The kinds of capital used in agricultural operations may be classified into three somewhat distinct groups: (1) permanent or immovable capital, comprised in the general term real estate, which brings certain but small earnings; (2) the movable inventory or equipment, tending to wear out and disappear with use, belonging either to the landowner or renter, subject to more risk than real estate and therefore to be made to pay a greater proportionate return on the investment; (3) the more temporary, annual or even seasonal capital, comprised in ready cash or what it buys for present needs, as labor, seeds, fertilizers, feeds and current supplies, the earnings on which must be large and usually in a different form from that in which the capital was invested. Capital in agriculture may be otherwise classified, however, for purposes of special discussion. The utility of a classification is to enable one to arrive at safe conclusions in regard to the nature and extent of the earning power of the different parts of the investment.

Working capital and equipment provide the facilities by which the man can utilize the forces and opportunities that lie at his hand. There are certain generalizations that will be useful, or at least suggestive, and these we may now consider. Having mastered some of the principles involved in the consideration of capital, and having acquired a point of view, the enquirer will then consult one or more reliable and thoughtful farmers that pursue the kind of enterprise in which he is interested. Examples of what such farmers would be likely to say are given in several articles. These articles are chosen without any desire to cover the field of agriculture or to represent all parts of the country, or even to make a connected presentation, but only to illustrate how the principles work out in special businesses or in concrete cases. Such articles necessarily raise the question of the general organization of the business.

In the articles that follow, the point of view is to record the judgment of thoughtful men as founded on experience; and since the whole question of the necessary investment in a farming business and the most effective division of this capital is of the greatest practical importance, particularly to the beginner, it has seemed best to give the discussion rather free and wide scope. There are fundamental theoretical questions that these articles do not pretend to discuss and which, in fact, are not relevant in this place (they may be considered in the fourth volume). Some of these are questions that have to do with the normal proportion that exists between the various kinds of capital in the most effective enterprises, as proportion of capital in land and land improvement, buildings, classes of equipment, labor and cash. There are no data in this country for the adequate study of this and other problems of applied economics in agriculture.

Plate XI. New farm lands in central Montana

GENERAL CONSIDERATIONS AS TO CAPITAL AND ITS DISTRIBUTION IN THE MANAGEMENT OF A FARM

By FRED W. CARD

The first requisite to the consideration of the capital required in any case is that the person analyze his business. He must cast it up, look at it from many sides, adjudge its relation to the commercial opportunities. The laws and generalizations that obtain in any good business procedure must be applied to the organization of agriculture.

One great advantage of agriculture as a business lies in the fact that it can be conducted with much or little capital, as conditions dictate. While a man with little capital must always work at a disadvantage, it is possible for him to begin with greater assurance of success than in many other lines of effort.

For purposes of analysis the capital demanded may be classified as follows:

A. PERMANENT OR INVESTED CAPITAL (not necessarily immovable):
  1. *Land:*
     - Natural value,
     - Land improvements,
       - Wells, drains, roads, fences, etc.
  2. *Buildings:*
     - Dwelling,
     - Farm buildings,
       - Building equipment,
         - Silos, stalls, shafting, etc.
       - Windmills.
  3. *Equipment:*
     - Teams,
     - Implements,
     - Live-stock used in production.

B. WORKING OR LESS PERMANENT CAPITAL:
  1. *Seed, feed, fertilizer and supplies.*
  2. *Market crops and market live-stock, growing or unsold.*
  3. *Money required to pay for labor and to conduct the business.*

Economists generally classify the elements of production under three heads. These, in agricultural operations, are represented by land, capital and labor. This classification considers labor as entirely distinct from capital, and aims to distinguish between natural agents, such as land or water power, and other forms of capital. Such a classification, while convenient from certain points of view, is inadequate for a detailed analysis of the business problems involved.

General view.

The original value of the land will represent, in many cases, but a small proportion of its actual value, since improvements which belong to the land as such, including wells, underdrains, roads, orchards, the cost of removing rocks, and the like, may come to represent a much greater value than the first cost. This is particularly true when the land is originally rough and stony, requiring a heavy outlay to bring it into productive condition.

The dwelling does not properly form a part of the farm capital, except in so far as it may be used for conducting farm operations. Circumstances combine the farmer's dwelling with his business; but, strictly speaking, this is a personal expense, the outlay for which may be much or little, according to the financial ability and taste of the owner, without materially influencing the results of the business. The farm investment properly includes all farm buildings, such as barns, granaries, hog-houses, poultry-houses and windmills. Connected with the buildings are the features of building equipment, or accessories, such as silos connected with the barns, special equipment for dairy or other work, improved stalls for live-stock, pulleys and shafting for use of power, and similar addenda. These improvements may come to be a prominent feature, representing a considerable part of the capital invested in buildings. The above forms of capital, all being included under the term real estate, are fixed capital in the sense of being immovable; but fixed capital in the sense used by economists includes also the permanent equipment demanded in conducting the business. This will embrace teams, implements and live-stock retained from year to year for purposes of breeding, or for other forms of production.

Fig. 172. A case in which land improvement must represent the chief land value. This area must be cleared of rocks and brush, and be underdrained before it can be considered as agricultural land.

The circulating or working capital properly includes that part of the capital that is used up and replaced from time to time in the conduct of the business. This will include seed, feed for animals (whether purchased or grown on the farm), fertilizer and other supplies. It will also include market crops and market live-stock growing or unsold. Such live-stock is represented by animals that are being grown for meat or for any other purpose that contemplates the sale of the animal itself, rather than retaining it for some form of labor or production. The circulating capital also includes a certain amount of ready money for conducting the business. This will be constantly passing over into forms, such as those already mentioned. It will also be needed in paying for repairs, supplies and incidental expenses.

The proper apportionment of the investment among these different forms of capital is a difficult but most important financial problem. The apportionment will vary with the character of the business, the location and the attendant conditions. No fixed rules can be given, but one fundamental principle should be kept steadily in mind, viz.: Production will be limited by the minimum amount of the weakest phase of the investment. If land is deficient, production cannot be carried beyond a certain point. With improper buildings, it is likewise hampered. With insufficient equipment, neither the land nor the buildings can be utilized to their full capacity. If labor, or other forms of circulating capital are deficient, production is governed by this factor, not by those that are abundant. The general law is that extensive farming demands the heaviest investment at the fixed end of the line, while intensive farming calls for an increase at the other end. The man who starts with little capital usually begins with a proportionately heavier investment at the fixed end. As the business increases and his conditions improve, or as competition forces more careful management, there is a gradual movement of the proportionate investment down the line from the more stable forms of fixed capital represented by the land itself, to buildings, equipment and working capital. More money is invested in drains or other land improvements, the buildings are improved and rendered more convenient by improved accessories and equipment; the movable equipment, represented by teams, implements and live-stock is increased; more labor is employed, and more money is used in the conduct of the business.

Fig. 173. A case in which land improvement is established and is incorporated in the purchase price.

Census figures throw some light on the average proportionate investment on farms in the United States, but do not give a satisfactory answer to the question of what this investment should be. The average farm values in the United States as given by the census of 1900, are as follows:

Total investment	$3,574 00
Land and improvements other than buildings	2,285 00
Buildings	620 00
Implements and machinery	133 00
Live-stock	536 00

The average expenditure for labor is given at $64, and that for fertilizers as $10. This, of course, does not include the labor of the farm owners. In the northeastern section of the United States, including New England, New York, New Jersey and Pennsylvania, the proportionate investment in farm buildings is much higher than in the United States as a whole. These figures show that, including the whole United States, for each one thousand dollars invested in land and improvements other than buildings, the amount expended in other ways is as follows:

Buildings	$271 33
Implements and machinery	58 20
Live-stock	234 57
Paid for labor	28 00
Paid for fertilizers	4 38

For each one thousand dollars invested in land, therefore, about five hundred and sixty-four dollars are invested in buildings and equipment. The two items showing the amounts paid for extra labor, in addition to that supplied by the farmer's family, and for fertilizers, represent but a small part of the incidental expenses demanded, and fail to give any clue regarding the amount of working capital involved. In the northeastern section, the proportion invested in buildings and equipment is much larger, being about equal to the amount invested in land.

Figures from a number of successful farms are available, showing the proportionate outlay and returns from those farms. An average from twenty-four farms, which may be classified as mixed farms, located in different parts of the United States, is as follows:

	Average outlay	Proportionate amount for each $1,000 invested in land
Land and improvements other than buildings	$7,935 87	$1,000 00
Dwelling	1,754 35	221 00+
Farm buildings	2,088 04	263 00+
Live-stock	1,342 31	169 00+
Team and tools	1,019 35	128 00+
Operating expenses	1,725 63	217 00+

Among these twenty-four farms were five that did not show a profit after adding to the operating expenses a charge of 5 per cent for interest on the capital invested, 5 per cent for depreciation, repairs and insurance on buildings, and 10 per cent for depreciation on teams and tools. On these five farms the figures were as follows:

	Average outlay	Proportionate amount for each $1,000 invested in land
Land and improvements other than buildings	$5,154 00	$1,000 00
Dwelling	1,160 00	225 00
Farm buildings	1,045 00	203 00
Live-stock	627 50	122 00
Teams and tools	737 00	143 00
Operating expenses	1,014 45	197 00

Nine of the farms show a net profit of over one thousand dollars per year after adding similar charges to the operating expenses. On these farms the outlays average as follows:

	Average outlay	Proportionate amount for each $1,000 invested in land
Land and improvements other than buildings	$11,000 00	$1,000 00
Dwelling	2,133 00	194 00
Farm buildings	3,061 00	278 00
Live-stock	1,745 80	159 00
Teams and tools	1,360 55	124 00
Operating expenses	2,495 04	227 00

These figures show the outlay to have been larger on the most profitable farms and smaller than the average on the unprofitable ones. The amount invested in farm buildings is proportionately larger on the profitable ones. The amount invested in live-stock is also larger on the profitable than on the unprofitable ones, but not larger than the total average. The proportionate amount invested in teams and tools is less on the most profitable farms than on the unprofitable ones, while the operating expenses are larger.

Figures are available from fourteen farms that may be classed as stock and dairy farms. The average outlay for these is as follows:

	Average outlay	Proportionate amount for each $1,000 invested in land
Land and improvements other than buildings	$15,965 71	$1,000 00
Dwelling	2,171 43	136 00
Farm buildings	2,554 65	160 00
Live-stock	4,060 28	254 00+
Teams and tools	1,297 14	81 00
Operating expenses	2,119 20	133 00—

The above figures show that on these farms, which are managed by successful, wide-awake men, for each $1,000 invested in land, between $630 and $800 is invested in buildings and equipment, the average of all being about $715. Exclusive of dwellings, the amount ranges from approximately $450 to $600, the average being about $520. Farm buildings alone require $160 to $275 per $1,000 of land investment, and teams and tools $80 to $150, the larger proportion being on the smaller farms. The operating expenses range from about $135 to $225 for each $1,000 of land investment, the average being nearly $200. While it is seldom necessary that the total operating expense of the entire year be on hand at any one time, there is great advantage in having a liberal supply of money available in order to be able to embrace opportunities for buying supplies at the most favorable time or to hold products until market conditions are right for their sale.

On the basis of the amount invested per acre, these farms show the following average investments for each acre available for farm purposes, excluding the amount occupied by buildings, waste land and woodland:

	Mixed farms	Stock and dairy farms
Dwelling	$8 20	$9 28
Farm buildings	9 76	10 85
Live-stock	6 27	17 28
Teams and tools	4 76	5 52
Operating expenses	8 06	9 02

A study of such figures as these should prove useful to any man contemplating investment in farm property. It may help him to avoid too heavy investment in land and the more stable forms of fixed capital, with too little in the less stable forms and in circulating capital. It is on the working capital that he must place his chief dependence for profit.

Special farming possesses an advantage over mixed-farming in the amount of equipment demanded, for the reason that less money will suffice thoroughly to equip a farm for a single line of production than for several lines. Not only is this true, but production on the special farm is likely to be conducted on a larger scale than on the mixed farm, so that implements that it would not be economical to own in the one case may be profitably employed in the other. The farmer who grows twenty-five acres of potatoes can afford to employ the best potato-growing machinery. The farmer who grows two acres must do without the more expensive implements or employ them at a loss, because the proportion of the fixed charges incident to ownership which must be borne by each acre is so great that it will exceed the saving effected in using the machine.

Further discussion of buildings. Fences. Trees.

Buildings represent a large part of the farm equipment. On stock farms they are relatively more important than on other types, though in mixed-farming the value represented is proportionately greater for the amount of stock kept than on stock and dairy farms. The dwelling, though naturally included in all census figures showing the value of farm buildings, is not really a part of the business. The ratio of the value of the buildings to land in the United States, as shown by the census of 1900, is about one to three and seven-tenths. In the northeastern section, including the Middle States and New England, it is one to one and five-tenths. These figures include the dwelling as well as the farm buildings proper. This means that in the United States as a whole one dollar is invested in buildings for each three dollars and seventy cents invested in land, while in New England and the Middle States one dollar is invested in buildings for each one dollar and fifty cents invested in land. On the twenty-four farms previously referred to the ratio is about one to two and one-third.

The building investment should be carefully studied. Buildings adequate in size and convenience are necessary to complete financial success, yet over-capitalization in this regard is of frequent occurrence. This is a common mistake of the gentleman farmer. Farms frequently sell for less than the cost of the buildings. It is difficult to draw the line between utility and personal gratification. Often the latter gains the ascendancy. While perfectly proper for a summer home, this should not be permitted in a business investment. Buildings that are used for only a short time in the year demand most careful scrutiny. The annual charges for interest, depreciation and insurance must then be apportioned to the one purpose for which they are used, and therefore the charge per day or week may be unusually heavy. When this expense must be charged to a single crop, as in the case of tobacco sheds, the cost should be carefully considered in estimating the net returns from the crop. Buildings deteriorate and involve constant expense for repairs and risk from fires. Changes in the scope of operations often render the structures unsuited to new needs, thus involving financial loss. The policy should be carefully determined and the needs thoroughly studied.

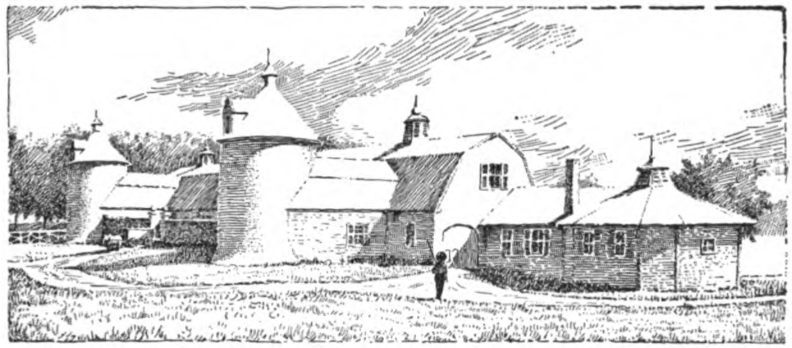


Fig. 174. Buildings that would represent over-capitalization in one of the capital-groups if they were on an ordinary farm.

Fences exact a heavy toll on many farms. While this is more properly a fixed expense, it is distributed over a period of years, and therefore may be considered in connection with the equipment. Careful study of the arrangement of fields, the plan of rotation, and abolishing fences not absolutely indispensable, will, in many cases, greatly reduce this charge.

Trees and plants form a very considerable part of the investment on fruit farms. Their value is difficult to determine, but may often surpass the value of the land itself. On such farms, the planting represents the most important part of the equipment. Its cost will depend much on circumstances, being governed by the locality, the type of planting, and the system of management pursued. A cost of fifty to one hundred dollars per acre is none too much to expect for bringing orchard fruits into bearing. If interplanting with vegetables and small-fruits is practiced, the return secured from them may equal or exceed this cost.

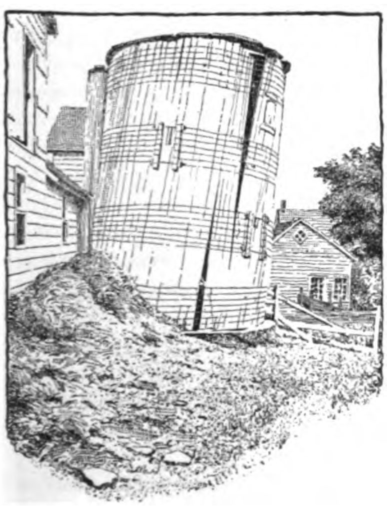


Fig. 175. A not uncommon example of under-capitalization. The result of a lack of analysis of the relative expenditure to be put into crop production and into buildings.

Implements. Teams.

Implements of improved pattern are more and more forced on the attention of the progressive farmer. The increasing complexity of the labor problem, and the difficulty of securing satisfactory or even unsatisfactory labor, may force the farmer to buy implements which otherwise would be unprofitable for him to own. Mechanical equipment which will replace unreliable human agents is steadily gaining in favor. If labor is available, several factors should be considered before determining on the purchase of a machine. The first of these is the cost of doing the given work by its aid. This cost is made up of a number of items, some of which may be easily overlooked. First comes the actual cost of the operation, as compared with the cost of doing it without the implement. To this must be added the charges which the ownership of the machine involves. This includes interest on the investment, depreciation in value due to use, accident, or improvement in the same type of implement, making it less efficient than newer models, the cost of repairs, storage and risk. The expense incurred in a change of machines made necessary by important improvements, may form a heavy item of depreciation. These items must be apportioned to the amount of work done. While such fixed charges may be light, if apportioned to a large number of units of work, they may be so heavy as to rule out the machine at once in the case of a small business. The amount of work to be done is often, therefore, the most important factor to consider. It is then necessary to know what the machine is likely to accomplish under average conditions and what its probable lifetime and depreciation will be. A further important factor to be considered is its efficiency,—whether the implement will do as good or better work than can be done without it. With such implements as the cream separator, this is the determining factor; with others, the efficiency may be practically the same with or without the machine.

It is significant to note that in the figures cited on the preceding pages the most profitable farms do not show a corresponding increase in the amount invested in teams and tools. The proportion is less on the profitable than on the unprofitable farms, though the total amount is more, since the capital invested is larger.

Teams involve a heavy expense for maintenance. It is a phase of the equipment that needs careful watching. Some saving may be effected at times in the cost of keeping by a careful study of rations, but this cannot be great. The important factor to be considered is the percentage of efficiency of teams kept, that is, the proportion of possible working time during which they are employed. A team which works only half the time that it might work, doubles the cost per hour for all work in which it is employed. No more horses should be kept than can be employed to advantage; then the work should be carefully planned to provide for as continuous use as possible. There must always be some idle time, but a study of the problem may greatly reduce it. A report which is before the writer shows that of two teams employed on the same farm, one worked 230 hours, the other 163 hours, during May, one of the busiest months. In August the same teams worked only 149 hours and 137 hours respectively. The cost of keeping these teams is about $25 per month. The actual team-work cost, therefore, from 10.8 cents to 18.2 cents per hour. The efficiency of the team itself is also to be considered. The most expensive team is not always the most efficient, but it is poor economy to use a team too light for the work in hand, or one that is not sufficiently well-fed to enable it to accomplish the full amount of work demanded. Depreciation in value represents a large part of the cost of keeping teams. The more expensive the animals the greater this charge becomes. For farm work it is often more profitable to buy cheap horses than expensive ones. In some cases they are really more effective in such work than high-priced, nervous animals, which must be carefully watched and guarded.

Working capital.

Labor is the one factor in the business that is most frequently lacking. Few farms are utilized to their most profitable capacity. The labor problem deserves much careful study. Among the farms previously mentioned, those which show greatest profit generally show also the largest outlay for labor. To urge that the farm should be utilized to its full capacity does not mean that every farm must be turned into a truck farm in order to employ more labor. It does mean that enough labor should be provided to make full use of the farm in the type followed. Greatly increased cost in the care of the crop and greatly diminished returns, due to the lack of labor to do things at the right time, are an almost constant experience on many farms. The cost of tillage in any hoed crop may be more than doubled by a few days of neglect; the returns at the same time may be cut in half. The margin whereby one man's production exceeds the cost of his services cannot be large. To develop a large and successful business demands that such margins from the labor of a number of men shall be combined. The margin itself must first be assured.

Ready money is in constant need, to pay for labor and to conduct the regular operations of the farm. Thousands of farmers are hampered for the lack of it, and lose each year far more than the interest charge would be on the capital needed for this purpose. Money is frequently needed to embrace special opportunities in the purchase of stock, equipment or supplies. The annual charge for feed and fertilizers can be greatly reduced by buying in quantities at favorable seasons. Sometimes it may be necessary to hold a product to avoid an unfavorable market; this practice can easily be carried to excess, involving the idea of speculation, but there are other times when it is simply good business policy to do so. Money to provide for extra labor when needed may be doubly well-invested, avoiding neglect and increased cost.

In conclusion, it may be said that the forms of capital that need most careful guarding are those less stable forms of circulating capital, beginning with ready money, and those phases of the equipment or business for which it is most likely to be needed. Permanent forms of invested capital are less likely to be neglected. The greater the competition, the greater, as a rule, will be the demand for working capital.

EQUIPMENT AND OTHER CAPITAL REQUIRED FOR A GRAIN-FARM, WITH SPECIAL REFERENCE TO CORN AND WHEAT.

By *Newton B. Ashby*

The years of the present century have witnessed a marked improvement in the prices of grain. Grain-farming, for the past half decade, has yielded larger net profits than has mixed-farming, that is, than general farming and live-stock combined. The rapid increase of urban over farm population, and the growing demand for export grain, promise steadily enhancing grain values. The objections to exclusive grain-farming are, the difficulty of preserving the fertility of the soil and keeping it in good mechanical condition, the waste of large quantities of forage which live-stock would consume and return to the soil as a fertilizer, and the months of enforced idleness on the part of the farmer.

Two methods prevail in the equipment of a grain-farm. The one is that practiced on a large scale by men who are not farmers, and is confined chiefly to the wheat-belt. A large tract of land is purchased and brought into cultivation as rapidly as capital can develop it. No buildings or permanent improvements of consequence are erected. The work is done under contract, or by gangs of laborers under direction of a foreman. The grain is taken directly from the thresher to the elevator. Having practically no investment except in the land, this method reduces the capital to the minimum, and has the advantage of quick returns; but it must, however, be regarded as an ephemeral phase of agriculture.

The other method is that practiced by the man who lives on the farm, and makes farming his vocation. The discussion to follow on capital and equipment is for the bona fide farmer, who desires both a comfortable home and an investment that will yield fair returns. For the reason that the quarter-section of 160 acres is within the means of a very much larger number of farmers than the section, the former has been taken for purposes of comparison, although the half-section or section will require a very small additional outlay of capital in buildings; and the half-section only about 50 per cent more of working capital above that required for the quarter-section. With large capital and a competent manager, the bigger the farm, even up to 10,000 acres, the greater will be the net profits on the outlay, because of the economies which can be practiced, and the more perfect system of rotations which can be carried out.

It is axiomatic in grain-growing that, when the net profit per bushel is small, the investment in permanent improvements and in working equipment should be at the efficient minimum. The equipment of a majority of the farms of the country is below this efficient minimum. It is poor economy on the part of the farmer to live in a small, unsanitary house with no conveniences; to house his horses in sheds or barns which furnish little protection from the weather; to leave his machinery and tools unhoused; to have insufficient granaries and cribs, and thus be under the necessity of marketing grain at harvest time.

The estimates.

The land investment will vary according to the location of the farm with reference to market facilities and to social and educational opportunities; to situation in latitude and longitude; to character of surrounding country; and to the quality of the soil and subsoil. In the states of the Middle West, known as the corn-belt, a quarter-section of land average in quality and location and under the plow, but without other improvements, will cost fifty dollars per acre, a total of $8,000. The improvements will cost approximately $5,000, distributed as follows:

House with modern improvements	$3,000 00
Barn, granaries, corn-cribs, tool- and machinery-house	1,200 00
Chicken-house	100 00
Ice-house, smoke-house and outbuildings	200 00
Groves for windbreaks, orchards and small-fruits	150 00
Fences	200 00
Miscellaneous	150 00

This estimate is for high-class improvements, and will be found ample and satisfactory. It is not to be presumed that a farmer could not succeed with much less expenditure, when as a matter of fact the majority of farmers manage with much less. For a half-section, the above improvements will be sufficient, with the exception of a small additional outlay for granaries and cribs.

The outlay in stock and machinery for operating this farm will approximate $1,500, as follows:

Four horses	$500 to $600 00
Two milch cows	80 00
One hundred chickens	50 00
Four sets of harness	75 00
Two grain wagons	125 00
One light road-wagon	60 00
Gang-plow, carrying two plows	50 00
Stirring plow	15 00
Disc harrow	25 00
Three-section harrow	25 00
Drill for seeding small grain	30 00
Broadcast seeder	15 00
Corn-planter	40 00
Two riding cultivators	50 00
Harvester	115 00
Mower	45 00
Hay rake	15 00
Sundries	100 00

A farmer with this equipment and with the assistance of a hired man during eight months, at $20 to $25 per month and board (with extra help at harvest, threshing and corn-gathering time), can readily handle such a farm if a judicious system of crop rotation is practiced. For a half-section, the working capital should be increased 50 per cent.

This farm, with a total investment of $18,000 to $20,000, can be made to yield, one year with another, an average gross income of $4,000 if skilfully managed. The operating expenses will aggregate $1,600 to $2,000, leaving a net income of $2,000 to $2,400, out of which would have to come interest, taxes, repairs and betterments.

In new regions.

In the newer sections of the country, notably the Dakotas and the Canadian Northwest, grain-farming can be undertaken with a much less outlay of capital. In the Dakotas it is estimated that there are approximately twelve million acres still open to homestead. In the wheat-belt of the Canadian Northwest there is quite as much. A part of these are first-class lands, which have not been taken up because of the distance from railway and market. The cost of a quarter-section homestead is nominal, consisting of filing and entry fees. Land, average in quality and in location, can be bought for ten dollars per acre. In the wheat-belt it is considered that a farmer to occupy fully his time should have not less than a half-section of land. On the basis of the half-section, the investment for land will be $3,200. The cost for permanent improvements and working equipment will not be greater for a half-section in the wheat-belt than that figured for a quarter-section in the corn-belt. In addition to the above, there must be added the capital required to bring the land from the prairie to a state of productiveness. The cost from the prairie to the first crop of wheat in the elevator is estimated at ten to twelve dollars per acre, when the work is done by contract. Some large landowners, who operate their farms by hired labor under their personal supervision, figure this cost as low as seven dollars per acre. If we take this latter cost at an average of ten dollars per acre, the working capital required to bring the half-section to the point of making returns will be $3,200. This charge should be regarded in the nature of a temporary loan to be repaid with the first crop. The cost of the second crop is figured at about four dollars per acre, and of succeeding crops at about six dollars. The average yield for the past decade for the wheat-belt of Canada has been about twenty bushels per acre, but the Dominion experiment farms are demonstrating that it is possible by good farming, and leaving the land fallow one year in three, to secure a yield of forty bushels. With equally good farming the investment in the wheat-belt would doubtless prove the more satisfactory if considered from the standpoint merely of net profits.

Fig. 176. Grain-farm in the Saskatchewan valley, Western Canada, in which capital is chiefly in land.

It must be kept in mind that all the preceding estimates are for the man with ample capital, who desires to bring his farm to a high state of efficiency in the shortest possible time. Every year, however, it is demonstrated that a man beginning with scanty working capital, either as a renter in the corn-belt or as a proprietor in the newer sections, can accumulate a competency. In farming, as in other callings, it is, after all, the man and not the equipment that counts.

THE EQUIPMENT AND OTHER CAPITAL FOR A GRAIN-FARM FROM AN ONTARIO POINT OF VIEW.

By *W. C. Good*

Grain-growing is now rarely the exclusive practice of the Ontario farmer. The opening of the great prairie districts, with their abundance of cheap and fertile land, has forced the farmer of eastern Canada to combine with the growing of grain for sale other agricultural industries, through which his relatively high-priced land may give to him better returns than if he made grain-growing his main or only source of income. In the West, there are still great unbroken areas covered by the remains of plants of countless seasons. For the most part, little labor is needed to make this land fit for wheat-growing. Timber is either absent or scrubby, stones are rarely troublesome, and the surface is generally fairly level. Moreover, the land can be purchased for a very small sum, and the equipment necessary for beginning operations is simple in the extreme. For these reasons, and others, the western farmer can afford to ignore, for the present, such questions as the depletion of the soil, the utilization of by-products, and the like.

Plate XII. Farm lands in Utah. Wheat-growing by irrigation

The eastern farmer, on the other hand, is placed in a very different position. Practically all the land has been already occupied for a generation, and therefore the original stock of available plant-food may be much reduced. It is, moreover, often rough and difficult to cultivate. If he wishes to buy a farm, the price he must pay is relatively large. Such conditions render it imperative for him to make the greatest possible use of all by-products, to follow a system that will maintain the fertility of his land, and to turn everything to account in the production of as high a grade of finished commodity as is possible. Even now, the earlier settlers in the West are beginning to realize the necessity of either migrating to the boundary of cultivation or adopting a system of mixed-farming; and we consequently find them taking up stock-raising, dairying and the like, in conjunction with their grain-growing. This transition, inseparable from the agricultural history of all newly developed countries, has already taken place in eastern Canada, and is now beginning to take place in the West.

If, then, we except the virgin soil on the borders of cultivated territory, and certain other special areas such as the volcanic plateaus of the Pacific region, it is difficult to find any farm that is devoted exclusively to grain-growing, and which, therefore, could properly be called a grain-farm. There are some farms, however, in eastern Canada on which grain-growing is the mainstay and chief source of income; and it is with such farms, in so far as they are devoted to grain-growing, that this article must deal. First, however, a few words may be said concerning the grain-farm of the prairies.

The capital with which the western settler begins operations need not be large. For a nominal sum he can get a homestead of 160 acres, and may, if he wishes, live in a "dugout" or a sod house until he can afford better. To begin with, a team of horses, a breaker plow and a set of harrows will be indispensable. A stable and some grain for the horses, a cultivator, a common plow, a seed-drill and a wagon will be scarcely less necessary. For the harvest, a self-binder, usually requiring three horses, can be either rented or bought. If the grain is to be stored at all after threshing, some sort of a granary will be necessary. If it is to be hauled directly to the elevator, no granary will be required. Such is the capital with which one may begin farming on the prairies.

Fig. 177. Establishment in which the stock-barns represent a large proportion of the invested capital. (Pages 173–177.)

If the beginner is successful, he adds to his initial equipment; or, if he has the funds and wishes to begin in a more satisfactory way, he makes a greater outlay at the start. He builds a house in accordance with his taste, his family and his means. He builds a granary and a good horse-stable. He buys labor-saving machinery for putting in his crop and for harvesting the same, using, as a rule, wide implements for tillage, and three-, four- or six-horse teams. If he is undertaking operations on a large scale he may use a steam-plow and other substitutes for animal labor.

The eastern farmer does not devote himself so exclusively to grain-growing as his western brother. Fruit, potatoes, dairy products, beef and bacon, breeding stock, are all produced more or less in conjunction with the ordinary cereals. Of the latter, wheat and oats, and in a lesser degree barley, peas, corn, rye and beans, are grown for sale. Those farmers who make grain-growing their chief source of income fall into two main classes: those who are too shiftless, too ignorant or too unfortunate to work into other, and, so far as outlay for capital is concerned, more expensive, lines of work; those financially encumbered, who follow grain-growing for a time because it yields the quickest cash returns, and, as soon as may be, introduce systems of mixed-farming.

The eastern farm is, on the average, neither so level nor so large as the western farm. Consequently, it is more difficult to use labor-saving machinery on it to advantage than it is on the prairies. Hence, we find practically no steam-plows; and seven-foot mowers and binders are rare. It is true that the Ontario farmer has learned to enlarge his fields and to use bigger and more efficient implements thereon; but, so long as the average farm does not increase materially in size, this sort of economy will soon reach its limit. It is practicable, however, at present, to make large use of double plows, wide harrows, cultivators and drills, and other means of saving man's labor. We cannot expect, however, that in this regard conditions will ever be as favorable for the average farmer of Ontario as they are for the prairie wheat-grower, and the former must be content to accept other advantages as compensations for this one decided disadvantage.

Land, fixtures and equipment.

In estimating the capital and equipment required for the eastern grain-farm, several chief items may be taken into consideration.

1. *Land.*—In the older-settled parts of Ontario, land is sold at various prices, according to its natural advantages (soil, surface, water and the like), its improvements (buildings, fences and others) and its situation (as proximity to markets). Prices vary from, say, $20 to $100 an acre.

2. *Buildings.*—The grain-grower will, of course, need a dwelling-place; and, as the size, cost, beauty and usefulness of such may vary infinitely, it would be vain to attempt to enter into details in this article. He will also need work-horses (oxen are yet used in places), and for these a stable, preferably covered by a haymow, is practically indispensable. A granary, too, is a necessity. Beyond these, nothing is needed and no other farm buildings are commonly used unless live-stock of other kinds is kept. Then cattle-stables, pig-pens, hen-houses, sheep-sheds, hay and straw barns, and the like, come into existence and necessitate a very considerable outlay.

3. *Animals.*—Three or four good horses should be sufficient on a 100-acre grain-farm. In addition to these, a cow may be kept to supply milk for the house, and a pig or two to consume refuse food and to be converted into pork.

4. *Farm implements.*—For a 100-acre farm it is customary to have some such implements as follows: One or two plows, a set of smoothing harrows, land roller, spring-tooth cultivator, disc harrow or the like, seed-drill, mower and hay rake, binder, wagon, and numerous other smaller articles. Threshing-machines are rarely owned by the small farmer; they are either owned jointly by a number of farmers or by one man who makes it his business to thresh over a certain territory during the season.

In addition to these main items, there are a few others, such as personal and household expenses, provision for contingencies, fencing, taxes and insurance, and so forth. Local prices it would be of no service to give.

As far as grain-growing is concerned, the writer does not think that barns are necessary for storing either the unthreshed grain or the straw, save in exceptional cases. Grain in sheaves can be easily and (ordinarily) safely stacked; and so also can the threshed straw. Unless the straw is to be sold, there is no object in housing it. It is usually either burnt, allowed to rot, or, preferably, plowed under; and for any one of these courses, housing the straw is of no service. The possession of a barn, with its annual wear and tear, and liability to destruction, for either unthreshed grain or threshed straw, is of questionable value.

Fig. 178. Extremes in tillage equipment in the same region. At the left, negro farming in the South. At the right, a 6-mule disc-plow and 4-mule mold-board plow breaking land in August, from which corn and cowpea hay have been gathered. Overseer in charge. Cane plots in distance.

There is no doubt that the general relationship existing between capital and output would be considerably modified if the average size of the eastern farm were materially larger. Larger implements, larger fields, less proportionate fencing, greater coördination of workers, and more economical methods in general could be adopted. Against these, however, must be set the disadvantages of having a proportionately large number of workmen; and nowadays it is a question whether the advantages of more economical administration are not more than neutralized by the disadvantages connected with the employment of hired help. Conditions may change in the future; but one must always reckon with the amount of capital that can most profitably be put into labor.

As already indicated, the grain-farm has only a temporary existence in special localities. So-called grain-farms, in districts devoted to mixed-farming, are operated by the shiftless, the ignorant, the backward, or the unfortunate. The equipment necessary for working a grain-farm, whether in the West or in the East, is comparatively inelaborate and inexpensive; and it varies much according to the size, soil, surface and other characteristics of the farm in question, as well as being dependent on the climate and the taste of the farmer. No figures and no rules will apply to all cases, or to the same case under all circumstances.

CAPITAL REQUIRED FOR THE STOCK-FARM

By *Herbert W. Mumford*

Stock-farming necessitates the outlay of considerable more capital than grain-farming. The money invested in live-stock is not the only factor calling for larger investment, as more and better buildings are required and the employment of more and better quality of labor is essential.

The equipment of the stock-farm will depend somewhat on the location and adaptability of the farm for breeding and rearing live-stock. It is assumed that the farm to be equipped possesses the desirable factors of a stock-farm, viz., a soil adapted to the growing of abundant forage at a minimum of expense, abundant supply of water easily accessible, plenty of shade, good fences that hold the stock without danger of injuring them, good mail, express and transportation facilities, and ample buildings of durable construction, attractive appearance and convenient interior arrangement. Buildings need not necessarily be abnormally expensive. As far as possible, the farm should furnish such feeds as are required for the maintenance and development of the live-stock produced. For example, if the stock-farm is to be devoted to the production of registered breeding cattle of some of the beef breeds, together with pork and mutton for the market, a location should be chosen where corn is relatively cheap. It is frequently better practice to buy a farm near, but outside, the corn-belt, owing to the high price of land in the corn-belt; and, as a rule, the improvements in the way of buildings and fences are not so good in the corn-belt as where mixed husbandry prevails.

Farms admirably adapted to stock-raising purposes may now be purchased in the Central West for $50 to $100 per acre. There is no objection to part of the stock-farm which is to be used for pastures consisting of rolling land, but it is a distinct advantage to have the plow-land reasonably level and free from stones and other obstructions that would hamper the use of modern labor-saving machinery. The equipment required will vary widely with the character of the soil, the contour of the land and the size of the farm. The small farm of eighty to two hundred acres is usually operated by the proprietor, he, together with one or two men, doing the farm work. The larger farms, consisting of four hundred acres or more, require that the proprietor spend his time as manager or superintendent; and this duty, well-performed, will leave little time for actual farm work. While the small farmer may engage in stock-raising with profit, the stock-farmer who conducts an extensive business is at a distinct advantage.

The economical investment of money in farm machinery is, in itself, a difficult problem. Such tools should be selected as are adapted for working to advantage the soil to be handled, and for seeding and harvesting such crops as are to be grown. Here, again, stock-farming requires a greater outlay for equipment. A greater variety of tools is required, as the crops grown for live-stock are likely to be more varied than those grown for market.

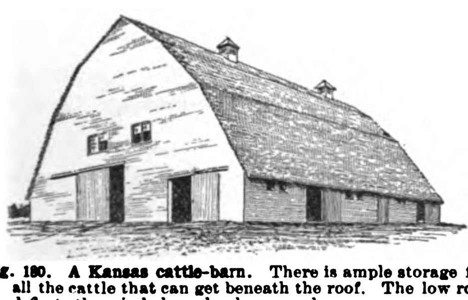


Fig. 180. A Kansas cattle-barn. There is ample storage for all the cattle that can get beneath the roof. The low roof deflects the winds harmlessly upward.

On a four-hundred-acre farm to be devoted to the production of beef, mutton and pork, the receipts from the sale of the cattle and hogs being relied on as the chief source of income, when corn, corn silage, oats and clover hay constitute the principal crops, the farm machinery should consist of the following: Two farm wagons, complete, and one wagon fitted with stock-rack; two gang-plows and one walking-plow; one four-section, four-horse spring-tooth harrow, and one four-section, four-horse, spike-tooth drag; three two-horse cultivators, one grain drill, one corn harvester, two mowers, side delivery hay rake, self-binder, manure-spreader, hay-loader, hay-slings and rope, hay-knife, corn-planter, seven-foot roller, four-horse disc harrow, end-gate seeder, ensilage machine, corn-sheller, platform scales, measures, shop tools, pitchforks, scoops, road wagon, surrey and four sets of heavy double harness, one set of light double and one set of light single harness, blankets, robes and other small equipments.

Fig. 179. A Wisconsin sheep-barn—rear elevation. It is of ordinary balloon frame construction, ceiled inside and outside, with shingle roof.

The live-stock to be kept might properly include: Two teams of draft mares to be used both for work and breeding purposes; two teams of work horses; one hundred registered beef cows, five milch cows, two registered bulls; one hundred grade ewes and two rams; and fifteen brood sows and one boar.

To conduct properly a four-hundred-acre farm devoted to the breeding of registered beef cattle and a variety of live-stock for market purposes, the following men or their equivalent would be required: The proprietor, who acts as manager and looks after the correspondence; a herdsman and one assistant, two in winter, to have immediate care of the registered herd; a foreman to direct the farm work, and two extra men for eight months during the growing season.

The estimates.

The capital and its distribution for equipment and operating expenses would be, approximately:

400-acre farm @ $80	$32,000 00
Farm machinery	1,500 00
Live-stock, including work horses .	18,150 00
Labor	2,265 00
	$53,915 00

The registered cows of the beef breeds were figured at $150 each and the herd bull or bulls at $1,000.

Income from the above investment may be as follows:

Eighty per cent of calves from 100 cows, or 80 calves, rendering available for sale eighty animals valued at $100 each	$8,000 00
100 fat hogs	1,000 00
Lambs and wool from 100 ewes . .	700 00
40 acres wheat	800 00
Three colts	500 00
	$11,000 00

No account is made of receipts from poultry, fruit or vegetables, which in some cases might amount to considerable sums. Nor in the expense account that follows is any allowance made for the purchase of concentrated feeds. The writer thinks that more than sufficient feeds will be grown for keeping the stock enumerated, and in case the purchase of nitrogenous concentrates is found advisable, enough of the feeds grown on the farm should be sold to cover such extra expenses, or more stock kept. In either instance, the relation between the receipts and disbursements of the farm would remain practically as here indicated.

Fig. 181. A new type of circular barn erected in Indiana. No heavy timbers are employed in the construction. The bending system of framing is used.

Statement of probable disbursements:

Six per cent interest on $53,915 investment	$3,235 00
Taxes, insurance and advertising	700 00
Annual depreciation in tools	300 00
Annual repairs and improvements	500 00
Labor	2,265 00
	$7,000 00

This leaves a balance of $4,000 for family expenses and profit. Many of these expenses would be nominal because of crops grown for home consumption. Family expenses vary too much to consider here.

LAND AND EQUIPMENT FOR A STOCK-FARM.—ANOTHER VIEW

By *Joseph E. Wing*

The equipment of a stock-farm naturally depends primarily on the kind of stock to be kept and the use to which the stock is put. The equipment of a farm devoted to growing swine in the Middle West may be very simple indeed, while the equipment needed to conduct successfully a farm devoted to pedigreed sheep or fine horses, or to dairy cattle, would naturally be much more complex and costly. Certain requisites of equipment, however, all stock-farms must have to be successful.

Land and pasture.

First should be placed the soil; and the nature of the soil not only modifies the original purchase price, but also influences the expenditure that must be added to it for fertilizers and other working expenses.

The soil for a stock-farm should be calcareous, that is, made up of decaying limestone. If it is based on a phosphatic limestone, this is an advantage. Such soils produce a superior race of animals, having greater vigor, more beauty and value than animals bred on unsuitable soils.

If the soil of the stock-farm supports, naturally, clovers of various kinds and the better sorts of grasses, such as Kentucky blue-grass (*Poa pratensis*), the manager may easily build thereon good animals of whatever breed he may choose. If, on the other hand, he must plant his farm on an inferior soil on which grass does not naturally grow well, and in which lime is markedly deficient, he should attempt to make up the lack by liberal applications of lime and phosphorus, together with what potash and nitrogen may be needed. Thus, the sorts of plants most necessary to support animals of a high-class will be stimulated.

If one may choose at the beginning, he will do well to found his stock-farm on suitable soil, rather than attempt to make a naturally unsuitable one good by applying minerals and manures. There is not very much difference in the cost of lands compared with their intrinsic worth. There may, for instance, be in the upper foot of an acre of rich soil based on limestone, as much nitrogen, potash and phosphorus as would cost, to buy and put there, some thousands of dollars, while the difference in price between that land and another with inherent fertility not more than a tenth as great would probably be less than $50 per acre.

Animals partake remarkably of the nature of the soil on which they grow. The sheep of New Mexico are distinctly different from the sheep of Montana. The horses of the fat limestone soils of England are large, the horses of the peaty, sandy heaths and moors are ponies. Even races of men

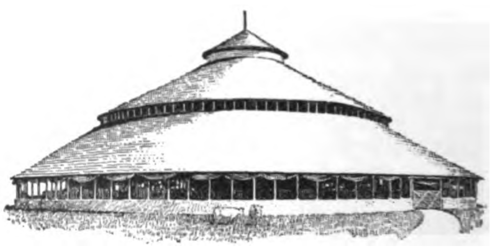


Fig. 182. Sanitary dairy-barn in the South. The open arrangement is well-adapted to the southern climates. Drop curtains furnish sufficient protection in inclement weather. (Fern Crest Dairy Farm, Sandersville, Ga.)

differ according to the soil on which they live and the water which they drink. Therefore, the first consideration in establishing a stock-farm should be the character of the soil and the kind of stock to which it is best adapted. Swine and poultry will thrive on any soil, since so large a part of their subsistence comes from outside sources. Grazing animals partake more directly of the outgrowths of the soil and are more directly influenced thereby.

A profitable stock-farm on which are kept cattle, horses or sheep, should be sufficiently fertile to yield the subsistence of the animals. There should be enough land to provide pasture, meadow and arable fields where grain, roots and forage may be grown. There is not usually on stock-farms sufficient profit to enable the farmer to buy a large part of the food for the animals.

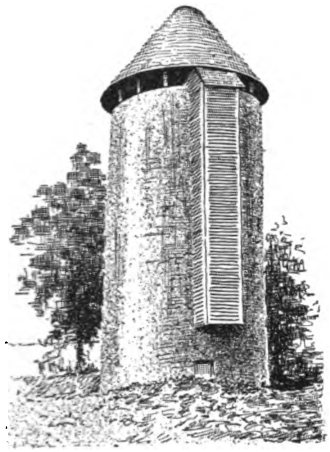


Fig. 183. The Wing cement silo. A durable, air-tight construction.

The equipment of the stock-farm should include a certain amount of pasture-land. Nothing will take the place of this. The right sort of pasture affords cheap subsistence, and any pasture affords the outdoor living without which animals will not possess native vigor and thrift.

When land is dear and the stock on the farm is in excess of its capacity to carry them on pasture, the pasture may be supplemented advantageously by feeding soiling crops in connection with the grazing. Racks may be set out on the poorer spots on the pasture-land, and filled daily with green clovers or other forage, mown and brought freshly to the spot. Or the soiling crops may be fed in the barn, where they will be consumed during the heat of day, the pasture being resorted to during the night and cooler parts of the day. Thus treated, animals thrive remarkably, since they have an abundance of fresh forage and are not dependent on the pasture-grass, which may fail during droughts.

Fences and buildings.

The further equipment should consist of strong fences and gates. The arable part of the farm may as well be in one large enclosure, on which no hoof shall intrude except as sections of it are set aside by hurdles or portable fences to be grazed by sheep or lambs. Fences should be so strong, tight and high that there never will be any temptation to the animals to pass them. The pastures should be divided into three or more divisions, so

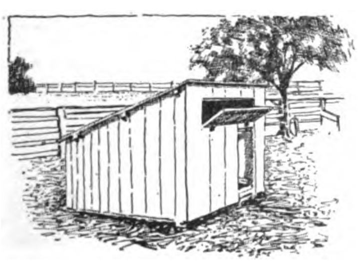


Fig. 184. The Bonham portable pig-pen, costing about five dollars complete.

arranged, when it may be done conveniently, that all will be entered from the barn lots. Gates should be built as strong as possible without destroying posts and hinges. They should be hinged to posts set four or five feet deep, thoroughly rammed with gravel when set. Posts of concrete reinforced with steel may be cheaply made, and when rightly designed will prove immovable fixtures.

The different barns for the stock-farm will conform to the use demanded of them, yet they will have some things in common. There will be a lower story, none of it beneath the ground, well-lighted by rows of windows, with the sashes hinged at the bottom and opening inward to permit fresh air to enter and flow over the animals without blowing directly on them. These basements will have in them no wooden sills, the posts resting on stone or, preferably, concrete piers. The floors will be of hard clay or concrete. Above this story will be one devoted to the storage of hay, straw or grain. Separate buildings will house swine, sheep, horses and dairy cows. The poultry will have their own building, and there is need of a large, simple shed for wagons and machinery. This should be so arranged that any machine or wagon may be driven

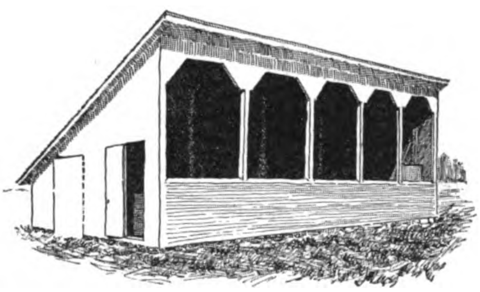


Fig. 185. A Maryland hog-house. This pen, facing south, admits the maximum amount of sunshine, at the same time that it gives good shelter and protects from the north and west winds.

beneath it and left there. The silo is indispensable when cows are kept in number.

Implements and machinery.

Given now the farm with suitable fields, with several small paddocks, not so small but that grass will grow well within them, with suitable buildings to care for whatever stock is to be kept, let us turn to the machinery of the farm. The plow is the primal implement; the best modern ones are walking-plows. Plowmen have largely discarded the sulky or wheeled types, as they cost at least twice as much, and unless carefully kept in order are less efficient, demanding also greater cost for repairs and maintenance. Plows are adapted to types of soils,—the chilled plows for stony ground, steel plows for loam, reversible plows for hillsides, where each furrow is turned down hill.

Steel harrows, with drag teeth that can be adjusted to different angles, are indispensable. Disc harrows are very efficient for soils without stone, especially when the land has run together by rain after being plowed, or to cut tough sods.

The disc harrows of the type having notches in the discs are of easiest draft. Disc plows are used in some soils, but are not generally so good as the common turning plow, since they are of harder draft and cut less deeply, though they pulverize while they turn. The plank drag, to smooth and pulverize after the harrow, is indispensable.

A roller is much needed; it may be of wood, iron or concrete. The iron rollers are durable and effi-

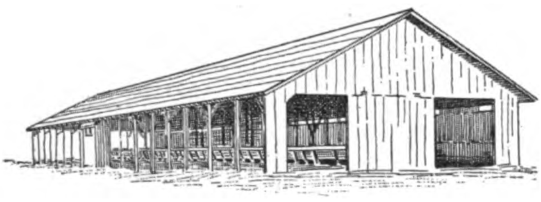


Fig. 186. Shed for hay feeding, showing simple construction. The feed-racks run lengthwise through the center.

cient, the concrete rollers best for grass lands, but too heavy for newly plowed fields. Rollers should be in two sections to admit of ready turning. The weight for meadows may be about 400 pounds per running foot; for cultivated fields, a third or fourth of that will serve.

The list of sowing machines, disc or hoe drills for wheat, oats, barley and grass seeds, machinery for planting corn in rows or checks, for planting one or two rows at a time, will depend on where the stock-farm is located. Harvesting machines for grain, and perhaps for corn as well, and farm wagons must be added to the equipment. The wagons should have wide tires and fairly low wheels, with platform beds seven feet wide and seventeen feet long, as low as it is possible to make them. On these beds are placed low side-boards for hauling grain or manure, while the platform serves for hay, straw or a dozen different uses.

The manure-spreader is a tool of great worth on the stock-farm, since by its use the farm manures are diffused over far wider areas and more evenly than is possible by hand. Thus the area of enriched soil is steadily increased, and the capacity of the farm to carry stock rapidly grows. Manures should be taken directly to the field and as fast as made.

There should be suitable dwellings near the barns and stables, for the attendants who look after the animals. On a stock-farm, the attention to small details is what brings success, and it is imperative that the attendants be close by.

Water supplies.

Water is essential. It should be pure, conveniently placed in each pasture and paddock and near each barn. If the source of supply is a living spring that will flow directly to the troughs, the best system has been reached. Stagnant ponds are very likely to breed and disseminate disease. Wells should be drilled to avoid pollution, and water may be pumped from them to storage tanks, from which it will flow to each trough. Wind power is the cheapest form of pumping energy, and is available in most parts of the United States.

Windmills should have solid anchorage to the earth. The towers should be at least twelve feet higher than surrounding trees and buildings. A small wheel on a high tower will prove efficient when a large one lower down will be useless because of the weakness of the wind.

Pipes carrying water from mills should be one and one-half inches in diameter, to avoid unnecessary friction. Water troughs are best made of concrete (Fig. 188); although galvanized steel makes a cheaper and a very serviceable tank.

The live-stock.

The capital required for operating a stock-farm will vary, according to the style of farm, from a few hundreds to many thousands of dollars. If the farm is to produce pure-bred stock for breeding purposes, the aim should be to invest in mother stock of very high quality, with sires of as good or better quality. In the breeding stock of such a farm most of the capital may well be invested.

A stallion, of the highest quality, among thoroughbreds may cost $40,000, and mares fit to mate him with from $10,000 upwards. The thoroughbred is the plaything of the very rich, with an occasional instance of a farm producing him for profit.

Among trotting horses, very high prices also prevail, when the highest quality is sought; and here, also, is the province of the man of wealth, though there is opportunity for men of moderate means to produce trotting horses that sell for gentlemen's drivers if they prove lacking in great speed.

The breeding of coach-horses and hackneys comes more within the province of the man of moderate capital. These mares may be had for sums from $500 to $5,000 each. It will be seen that, with any type of pure-bred horses, the sum invested in mother stock must be large; $10,000 to $500,000 may well be spent in buying the foundation stock.

The breeding of draft-horses is still more within the power of the man of moderate capital, as he may use the mares to do much of the farm labor, and the colts will be a side issue of profit. Good draft mares of Percheron or Clydesdale blood may be bought unrecorded for $250 to $500 each, and when bred to a suitable stallion will bring colts worth as much as themselves. Such mares should not be overworked, but may do regular, moderate work to their own advantage and to that of the colt.

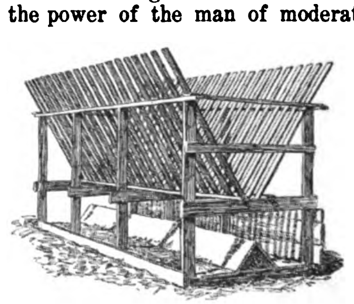


Fig. 187. A portable feed-rack for sheep.

In breeding pedigreed cattle, large sums are needed to secure the best animals. Cows of the leading breeds may be said to range in price from $200 to $1,000 each, with some exceeding that sum. A cattle-breeding farm has in it much less of risk and expense than a horse farm, since cattle require little training and less attention than horses.

When dairying or the production of beef is the object rather than the production of breeding stock, mothers will cost much less, beef cows $40 to $75 each and milking cows $25 to $100 each.

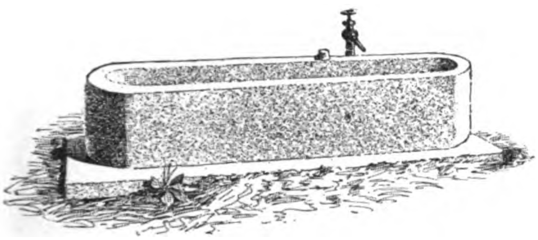


Fig. 188. The cement watering trough is supplanting the fast-decaying and leaky wooden troughs.

Very good sires may be had at prices ranging from $75 to $200 each.

With sheep, the stocking is comparatively cheap, unless a stud flock is established. Good breeding ewes seldom cost more than $5 each, and may often be bought for considerably less, while a ram of high class can be had for $25 to $50. It should ever be remembered that the ram is half the flock.

Pigs are comparatively inexpensive, especially as they are prolific and not many mothers are needed. Good sows can usually be bought for $15 to $30, and common ones for half this amount. The common ones may produce as good offspring as the others if pork and not breeding stock is the object.

Aside from the capital required to equip with tools and stock, there is the need of money to conduct the year's work. This will amount to more than the novice has been led to expect. Expenses vary immensely according to the type and extent of the farm; but the writer, on a farm of 320 acres, growing about 350 tons of alfalfa hay, 3,500 bushels of maize, and 1,200 bushels of oats and barley, the whole fed to fattening lambs, calves and pigs, excepting what is fed to the farm teams and a few colts, finds that the labor cost is about $2,000 per year, with an outlay for repairs and machinery of about $500. This is in Ohio, where labor is good and not so highly paid as in some other parts of America. Probably the cost of tools and machinery, including wagons, would be about $2,000 and of the working horses (10), $1,750.

SETTING UP A FARM DAIRY BUSINESS IN THE NORTHEASTERN STATES, AND WHAT IT COSTS.

By *Jared Van Wagenen, Jr.*

The amount of money invested in a dairy-farm will vary widely, of course, with the location of the farm, the character of the buildings and allied equipment, and the type of cows that go to make up the herd. In a general way it may be said that in the North Atlantic and Ohio valley states, dairying, by a process of natural selection, has been most highly developed on lands that are hilly, stony, or ill-adapted to general or grain-farming. A notable illustration of this is Delaware county, in New York,—a county of narrow valleys lying between rugged hills, where much of the land is suitable only for pasturage; thus, by force of circumstances, there has been built up what is perhaps the most intense and highly specialized dairy industry in the country. Nothing surprises the visitor so much as the great number of cows maintained in districts which for general farming purposes would be esteemed well-nigh worthless. Yet it is only fair to say that these dairy-farms labor under the great disadvantage of being largely dependent on purchased grain to supplement the natural resources of the farm. The cow is here in great numbers because dairy-farming is the type of agriculture particularly adapted to this region. When the land is fairly level, fertile and easily plowed, men have not, as a rule, been willing to milk many cows. It should be noted, however, that there is a strong tendency for the cow to push her-

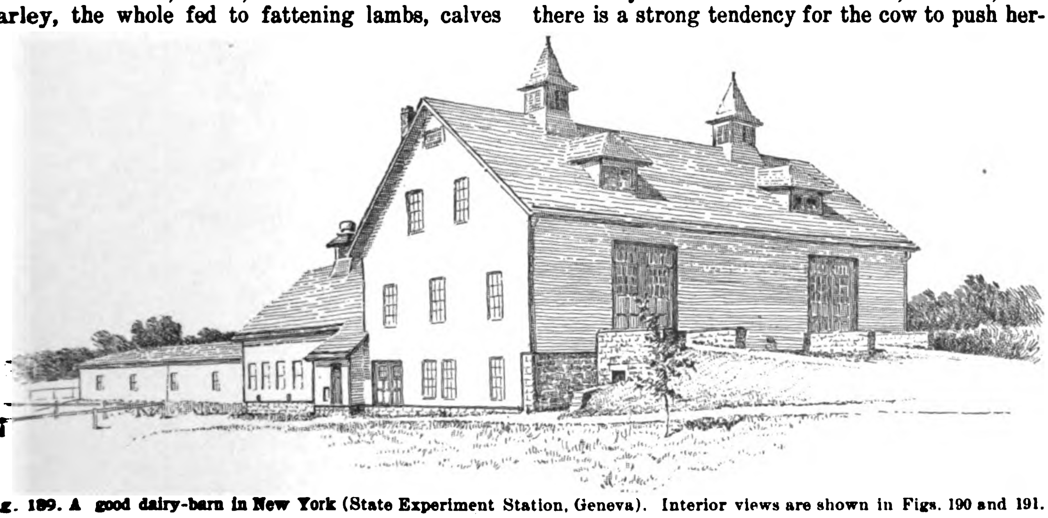


Fig. 189. A good dairy-barn in New York (State Experiment Station, Geneva). Interior views are shown in Figs. 190 and 191.

self into what were formerly the general farming regions, especially as decreasing fertility has shown the necessity of a policy of animal husbandry rather than soil-mining. In the Middle West especially, a great dairy industry has been developed on some of the most fertile and valuable lands.

From what has been said, it follows that the farms of the recognized dairy districts are not generally among the best or highest-priced lands. Still, this is a wrong conception, because good land is worth as much for keeping cows as for any other purpose. Lands in the dairy regions of the East are certainly not high-priced. There are farms with some good level fields, large areas of excellent upland pastures, fair buildings and reasonably convenient markets, that can be purchased for small amounts—say $25 per acre. Some of these cheap farms have large dairy possibilities, but nearly all the barns will need extensive alterations before they will conform well to modern requirements for a dairy-barn. Yet the massive hewn frames of old-time barns are generally a valuable asset when it comes to repairing them. There are few dairy-farms in the East, even with good land and up-to-date buildings, that, when offered for sale, will bring more than $75 per acre.

The amount of land required per cow will vary within the widest possible limits, depending much on the natural capabilities of the soil, and still more on the system employed and the skill of the farmer. There are so-called dairy-farms where a careless and slipshod husbandry requires 200 acres for the support of a dozen or twenty cows. Under ordinary New York conditions, thirty cows are frequently kept on 100 acres, while further south, where the two-crop system can be followed and where the herd is maintained in summer by

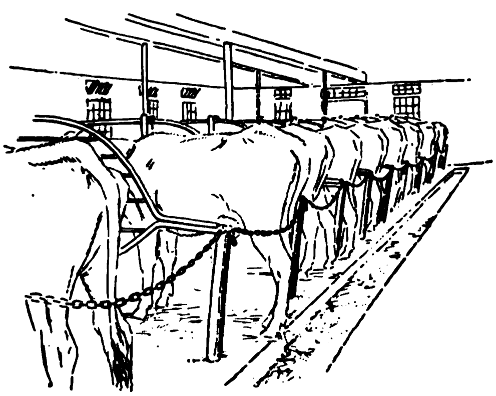


Fig. 190. A sanitary dairy stable in which the cows face away from the light. All corners are rounded to avoid dust.

soiling rather than pasturage, there are men who are approaching the ideal of a cow to every acre.

The buildings and apparatus.

In the equipment of a dairy-farm there are no questions more important than those connected with the construction and fittings of the barn; for it is here that the animals will spend at least two-thirds of their lives, here their food supply will be stored, and here the labor of caring for them will be performed. Hygienic stabling demands at least a reasonable amount of light—direct sunlight as far as possible—and the best attainable ventilation. The

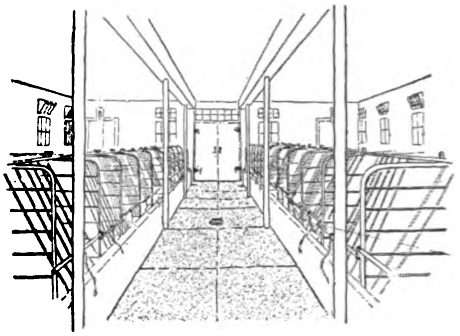


Fig. 191. Interior of a sanitary dairy-barn. New York State Experiment Station.

older practice was to endeavor to provide pure air for the animals by giving a large cubic space per cow, without making any especial provisions for introducing a fresh supply. The more recent idea is to have rather small, low stables, and then, by a system of ventilating flues, constantly to remove the vitiated air and bring in fresh air in its place. The idea has been popularized under the name of the "King system." In a general way, stables should be built mainly above ground, and not virtually basements, as was the prevailing practice a generation or two ago. Stables should have an abundance of windows on all sides where light is available. Cement rather than plank floors may be regarded as almost indispensable. The first cost of such floors is not much greater than of well-laid plank, and they are far more satisfactory in every way, being smooth, water-tight, sanitary and practically indestructible. If distinctly high-grade milk is to be produced, a tight-matched ceiling is very desirable to prevent dust particles falling into the milk from overhead. The temperature of a good cow stable should never fall to freezing even in the severest weather, and this condition may easily be attained by a double-boarded wall, i. e., by matched lumber and building paper on each side of the studding, with a dead-air space, or, what is more efficient, a chaff packing between. With driving winds and a temperature twenty degrees below zero, a stable must have animals enough to fill it fairly well and not have too high ceilings.

It is not easy to overestimate the importance of securing an arrangement of barns that will make it convenient to "do the chores." Many barns have been built where the health and comfort of the cows have been well looked after, but almost no thought has been given to the problem of getting the feed to the cows and of removing the manure. So we find hay dragged by the forkful through long, narrow alleys, ensilage carried in baskets from remote corners, and manure removed in wheelbarrows—very unnecessary burdens added to a task which is at best laborious. A very con-

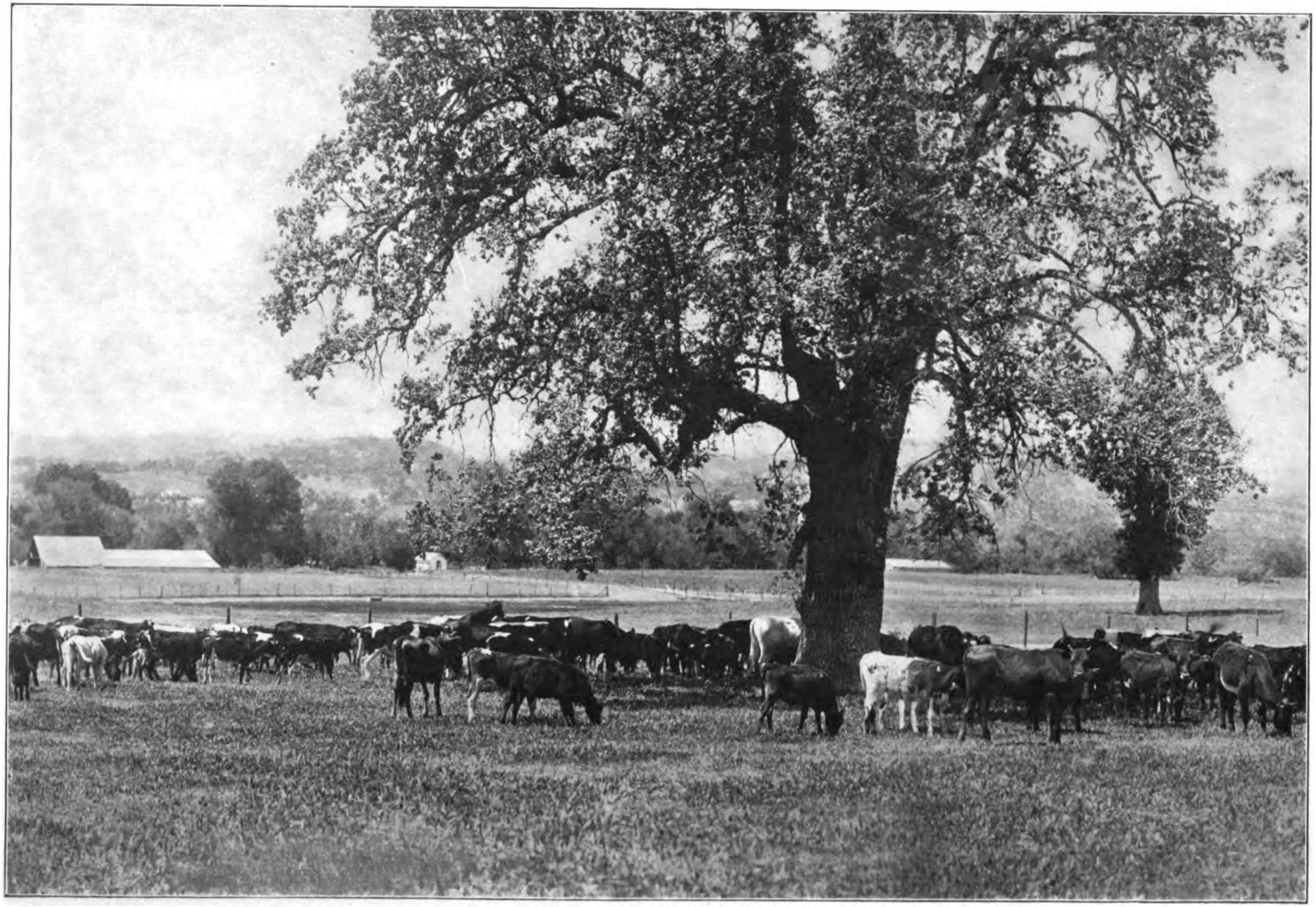


Plate XIII. Farm lands in California. Santa Ysabel Hot Springs, San Luis Obispo county

venient arrangement is also one of the cheapest so far as cost of construction is concerned, and is, moreover, entirely consistent with the best stable conditions. We are approaching a common style of dairy-barn architecture just as a set type has been reached in the construction of some other buildings, and the prevailing cow-barn of the future will probably be a two-story building, thirty-two to thirty-six feet wide and as long as may be necessary. This will afford room for two rows of cows, each facing outward toward the light, with a feeding alley next the wall on each side and a single driveway in the rear about ten feet wide, through which a team can be driven from end to end of the building for the removal of the manure. If the posts run eighteen to twenty-four feet above the stable with the usual style of roof, there will be room above for the storagè of hay, unthrashed grain, purchased foods and some farm tools. Hay chutes from the mows above will drop the hay into the feeding alleys in front of the cows, while a chute for bedding will drop this into the alley behind them. Spouts will conduct the grain from bins above into feeding boxes located at any convenient point. Such a barn should be flanked by two silos, one on each side, where the ensilage can be thrown directly into the feeding alleys. A barn of this type certainly reduces the labor of caring for the cows to the lowest terms, and still maintains a very economical form of construction. Other considerations may vary this precise plan—may, for example, dictate the addition of an L for box stalls, as in the barn shown in Fig. 192, which is further modified by having three stories and by having the space beneath the bridge to the upper floor serve as a place for the farm engine and also for a granary; but the essential plans, so far as the width of the structure and the position of the silos are concerned, can hardly be changed without the sacrifice of desirable features.

The cost of such a barn will vary within wide limits, according to the finish and the locality where built. As an indication, it may be said that a builder of some experience in eastern New York estimates that a barn like that outlined above can be put up in excellent shape, well-roofed and painted, but without ornamental features, for about $30 per running foot. A barn of this type sixty feet long would then cost $1,800, and should store food for and stable, say, twenty-five cows and four horses, and leave room for three good-sized box stalls for calves and young stock. Such a place should have preferably two silos with a combined capacity of about 125 tons, and these, if purchased from a leading manufacturer ready to erect, inclusive of roof, would cost $135 to $145 each. For eastern American conditions, in most localities, a silo is a regular part of the farm equipment. This is not true north of the limit of maize-growing or where the condensaries refuse to receive milk made from ensilage.

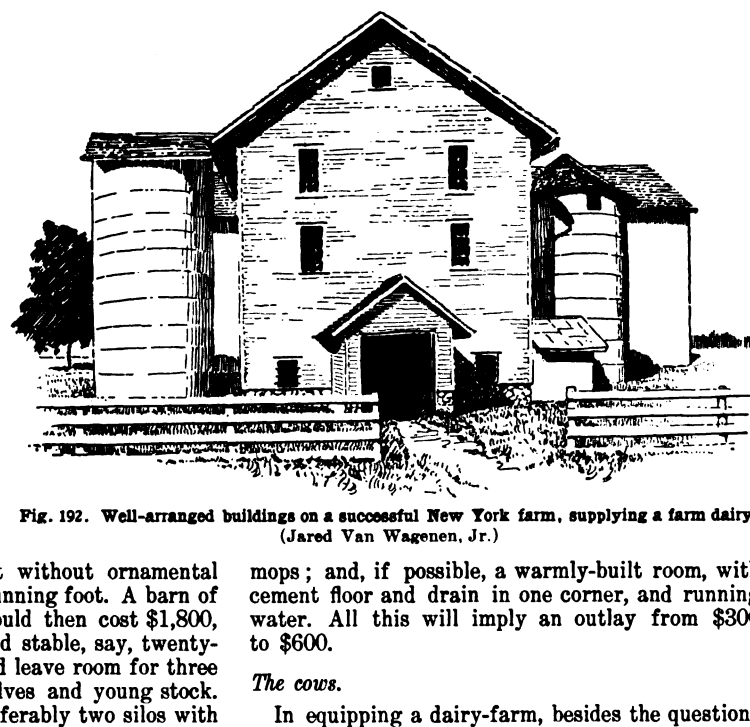


Fig. 192. Well-arranged buildings on a successful New York farm, supplying a farm dairy. (Jared Van Wagenen, Jr.)

Stable construction will be essentially the same whether the milk is to be sold raw or taken to the cheese or butter factory, or made into butter at home. But the equipment will vary considerably. Let it be said in passing, that within a few years there has come about the production of "certified milk," or sanitary milk,—a product made with especial attention to care and cleanliness at every stage, which is sold at prices usually two or three times as great as that of the ordinary commercial article. The especial object sought is to keep down the amount of germ infection in the milk, and this requires a special equipment of stables, and, to some extent, of apparatus. For ordinary factory or market milk, the utensils are exceedingly few and inexpensive. They comprise little besides the milking pails, a strainer, a simple cooler or aërator, and the cans for taking the milk to the station or factory. But, when the butter is made on the farm, the question of apparatus becomes more complex. In addition to the pails and cans, there will be needed a small boiler and engine, a cream-separator with a capacity of 250 to 1,000 pounds of milk per hour, a revolving churn, a worker, a printer, and the various minor utensils such as thermometer, scrub-brushes and mops; and, if possible, a warmly-built room, with cement floor and drain in one corner, and running water. All this will imply an outlay from $300 to $600.

The cows.

In equipping a dairy-farm, besides the questions of land, buildings, apparatus and utensils, there remains the item of cows—the vital machines whose function it is to convert the raw material of the farm into milk. So far as the capital required for investment in the herd is concerned, it is possible to give a fairly satisfactory estimate. Milch cows seem to be more stable and better established in price than any other farm stock or product. Taking "fresh" cows as a standard, the price has, on the whole, fluctuated remarkably little for many years. Such animals of mixed or unknown breeding, if fairly young and sound, i. e., with four good teats, tractable, and not blemished or out of shape, will range in price from $30 to $60, the great majority of them falling between $35 and $50. And let it be said that for purely economic milk production, when no question of selling the progeny is involved, carefully selected grades and "natives" may be quite as valuable as pure-bred animals. Doubtless there will be a greater number of inferior animals among their descendants, however, and they will lack the finish and uniformity of a herd bred to one common type. In a general way, it may be stated that a good cow has her selling value doubled by being registered in one of the standard herd associations, i. e., by having a recorded history of ancestry. Most breeders will sell good, mature, recorded cows for, say $100, although occasional individual animals sell for several times this sum.

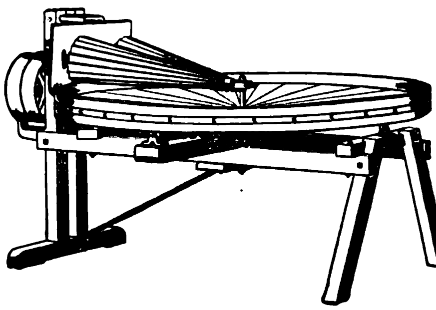


Fig. 193. Butter-worker for a home creamery.

The writer feels sure, from experience, that it is possible to go into eastern New York, and, by using care and good judgment, pick up a good, creditable herd of grade cows at an average cost of not more than $45. A bull of the very best breeding and individual excellence of the desired breed should be chosen, and a persistent policy adopted of raising the heifer calves and discarding those which fail to be among the best animals. While usually the system of rearing the calves necessary to maintain the herd is to be strongly advised, yet when the area of the farm is restricted and other lands are not available or are very high-priced, it may be wisest to depend on purchasing fresh cows, feeding them liberally until they begin to go dry and then selling them to the butcher. This is the plan that is followed on some of the most successful dairy-farms in the neighborhood of the big cities.

It must be remembered that the equipment of a dairy-farm in non-essential details may vary within the widest limits. The cow asks only palatable, nutritious food, comfortable stables, and kind attention. She cares nothing for architectural ornamentation, or even for the refinements of paint and finishings. But the esthetic tastes of her owner, and the satisfaction and advertising that come from a well-appointed stable, may be ample justification for the elaborate equipment of some dairy-farms.

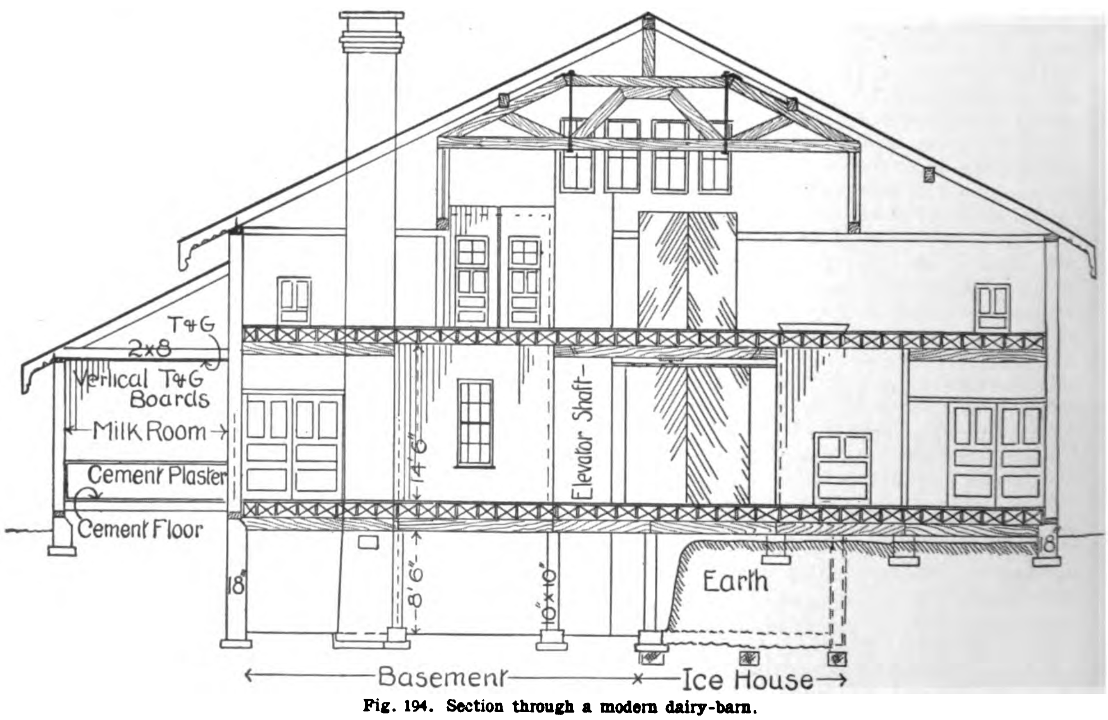


Fig. 194. Section through a modern dairy-barn.

CAPITAL REQUIRED FOR A DAIRY-FARM FOR THE MIDDLE SOUTH

By *M. A. Scovell*

In the equipment of a dairy-farm three things are essential: the farm itself, the herd, and proper buildings and conveniences.

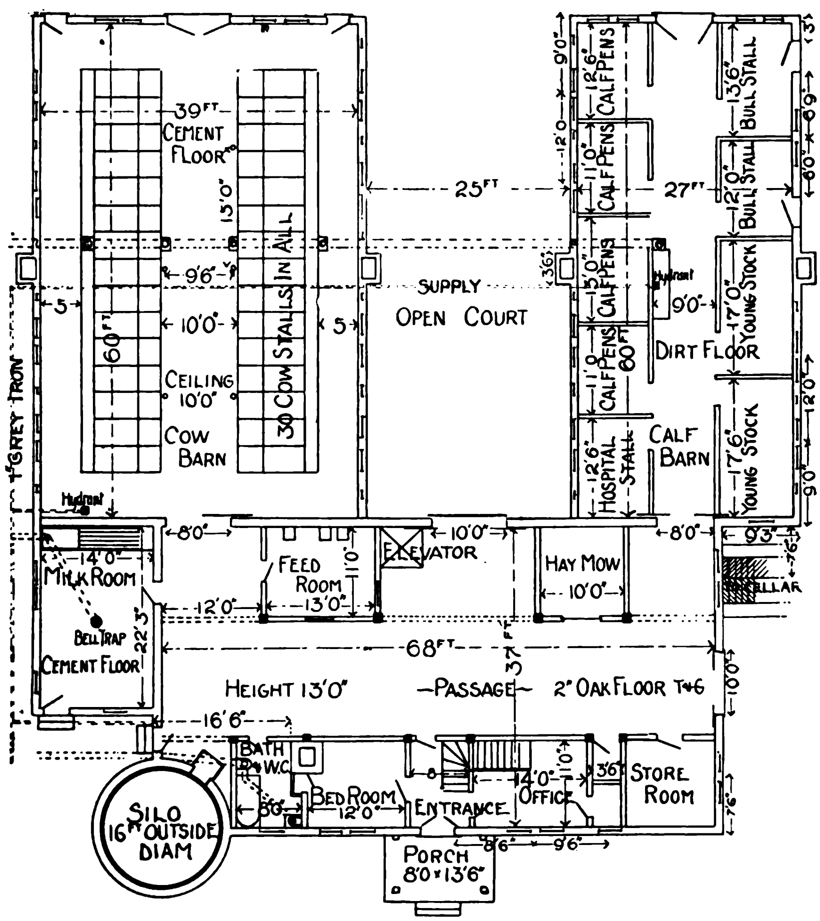


Fig. 195. Plan of a modern dairy-barn, showing ground dimensions.

In the Middle South the climatic conditions are favorable for dairy-farming, and in the greater part of this area pasture-lands are abundant and well-watered by running streams and springs. The winters are never severe. Pasturage can be had nearly the entire year. Under such conditions, where it is unnecessary to confine cows closely in stables even in winter, they are healthier, grow larger and produce more milk and butter than where by necessity they are more closely confined. The dairy-farm, therefore, in such climate should be mostly in pasture. There should be at least one acre of pasture-land to each head of stock. But some of the land should be reserved for cultivation. All the corn for silage should be raised on the farm and, if possible, all the hay also; and at least twenty acres should be reserved for the house and garden and the raising of fruits. The pasture-land should be divided into fields or lots for the purpose of not allowing any one part to be continually pastured. The section of land reserved for corn, silage, and the like, can be put in rye in the fall and used for early pasturage in the spring. The farm should be selected with reference to whether the object is the production of milk, butter or cheese. If the object is to furnish milk, then the farm should be near a large town or city, or on a line of railway where the milk can be marketed conveniently.

The animals.

It is still more important to select the dairy herd. The profits in a dairy depend almost entirely on the selecting of dairy cows. Only strong, vigorous animals and those giving a large quantity of milk should be selected or retained in the herd. Individual records of each cow should be kept in order to show which are profitable and which are being kept at a loss. The milk of each cow should be tested once a month for butter-fat. When calves are raised, the bull should be pure-bred, and it would be better if the cows were also; but, if the cows are not pure-bred, a few should be selected from time to time, not so much on pedigree as on their milk and butter production, and with finely bred bulls the calves of such cows will soon build up a herd. The herd should average at least two gallons of milk a day per cow the year round, and at least one pound of butter per day.

The barn and equipment.

Whether for milk, butter or cheese, the dairy-barn should be constructed on sanitary principles. Pure milk from healthy cows with sanitary surroundings is worth in large towns and cities thirty to forty cents per gallon, while milk produced in unclean surroundings averages less than fifteen cents per gallon, and often its sale is prohibited by municipal ordinances. It is essential to have a barn light, well-ventilated and convenient. A convenient barn is one with the main part for office and dairy rooms, with two wings, one wing containing the

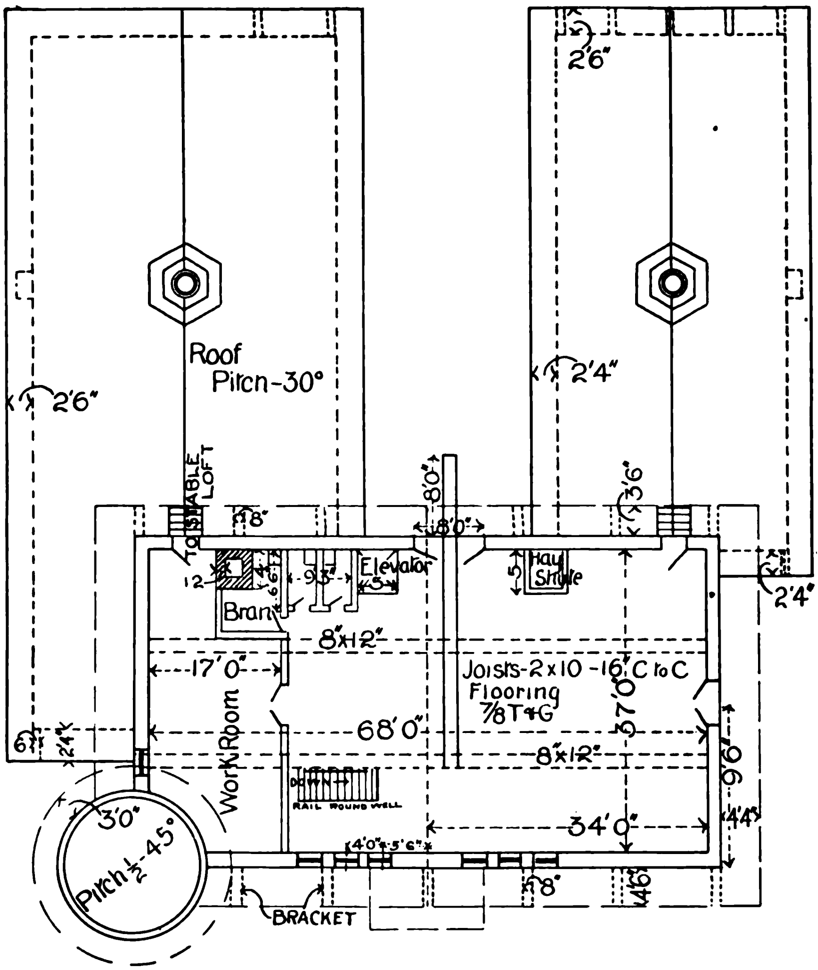


Fig. 196. Upper floor of modern dairy-barn, showing ventilator outlets on sheds.

stalls for the cows in milk, and the other for calves and springing cows. The floor of the wing containing the cow stalls should be of cement, the other floor of clay. Details of the plans of a modern dairy-barn and the construction are given in Figs 194, 195, 196. In these details will be found the dimensions of the barn, each stall, and other things necessary in the construction of a barn. One of the most essential things about a dairy-barn is the ventilation, and the King system (See Chap. VII) seems to answer this purpose. The milk-house and place for the care of the milk and making the butter are as essential as the dairy-barn itself. The milk-room is a part of the barn in the accompanying diagrams, and it is very convenient. The floor should be of tile or cement, and large enough to contain a good-sized sink, proper shelving, refrigerator, separator, churn, sterilizer for bottles, milk-bottling machine, cans and other equipment. When cheese is made, a cheese-room so constructed as to have equable temperature should be added to the dairy room. A silo is essential to a modern dairy. When the dairy-farm is not located conveniently to a city, an ice-house is one of the essential buildings. It should either be put in the basement of the barn or made a separate building.

No dairy-farm should be without a silage cutter and shredder and an engine to produce the necessary power for running such a machine. An eight or ten horse-power gasoline engine answers the purpose well. It is economical to run the hay through a cutting machine as it is brought to the barn and blow it into the loft, where it can be dropped through trap-doors to be fed below. This is true also of the fodder, which should be shredded. A water heater and a sterilizing apparatus for bottles and utensils, a separator, a milk cooler, sanitary milk buckets, a good churn, and, when cheese is made, cheese vats, with bottles, cans, and so forth, are essential to every dairy. In a dairy with less than twenty-five cows, a hand separator may answer the purpose. It is better, however, to have the separator run by power when there are more than fifteen cows.

The estimate.

The cost, at least so far as the land is concerned, depends largely on the location of the dairy. If near a large town or city, the land can not be had for less than $75 to $200 per acre. When it is located some distance from a town and railroad, land can be had from $10 to $40 per acre. A good, convenient barn for a small herd would cost at least $2,000. A large milk farm furnishing good sanitary milk to a city, or one of 100-cow capacity, will require a barn costing $8,000 to $10,000. This includes the dairy house. The other equipments will cost $1,000 to $2,000.

EXAMPLES OF WELL-CONCEIVED POULTRY-FARMS, AND DISCUSSION OF CAPITAL INVOLVED, FROM THE EASTERN POINT OF VIEW.

By *A. F. Hunter*

There has come a decided change of front in the poultry business, and poultry-farms are now being developed that are commercially successful, whereas but a few years ago failures were the rule. A great improvement in appliances for conducting the business on a large scale, coupled with more intelligent methods of operating large poultry-farms, has effected this change of front, and today there are poultry-farms on which two dollars net profit is cleared annually from each head of laying stock. The three most important points in this improvement are better housing, more intelligent feeding and handling, and great gain in the methods of artificial hatching and rearing. The better housing has taken the form of opening the houses to fresh air and sunshine, a reform which is in keeping with the more hygienic housing of human beings. The more intelligent feeding and handling takes the form of dry-feeding (or "hopper-feeding" as it is sometimes called) and consists of keeping part or all of the food before the birds all the time, so that they eat slowly and naturally, —which "natural" feeding gives decidedly better results in general health of the flocks and greatly reduces the labor charge. The great gain in methods of artificial hatching and rearing is seen in the improved incubators and brooders, with which should be coupled the better knowledge of conditions essential to best results from their operation.

A New Jersey example.

The amount of capital required for a poultry-farm will depend on the extent of the operations, and, in a measure, on local conditions. At Lakewood Farm, located at Burrsville, near Lakewood, New Jersey, an up-to-date poultry-farm of the best type, the total capital invested in farm, buildings, appliances and stock is $14,000. On this farm in 1904 were kept 3,000 head of laying stock, which paid the owners, after allowing 10 per cent for depreciation and 5 per cent interest, a little over $7,000 net profit. On this farm additional buildings are being erected, which means more capital invested, and it is the intention to develop it to a capacity of 10,000 head of layers. This is a purely commercial poultry-farm, the chief aim being eggs for market, and during the year under review the operations were wholly along that line, the only departure from it being the sale of 400 mature pullets in the fall of that year. To this profitable line of work there is being added the sale of breeding stock in the fall and winter, of eggs for hatching in spring, and newly hatched chicks,—all three additional sources of profit.

The type of poultry-house adopted at this farm is 128 feet in length and 16 feet in width, divided by board partitions into pens 16 x 16 feet each; in each pen are housed 50 layers. The front of the pen is of three windows, the two at the side being fitted to slide in front and rear of the one in the center, making two thirds or less of the front open at pleasure. A roosting apartment, lifted three feet above the floor and which may be closed by a swinging curtain in front, is across the rear end of each pen; exercising yards 90 feet long by 16 feet wide extend south from each pen. As the soil of that section of New Jersey is clean sand, there is no poisoning of the ground by the droppings, every rain-storm or heavy shower effectually cleansing it.

A commodious grain-storage house, 30 x 30 feet in size, is located in the rear and conveniently near the stock houses; the farm offices occupy one end of this house, and the well-lighted basement is occupied by the twenty-five 360-egg incubators used for hatching the chicks. A brooder house 110 feet long, which was formerly equipped with a hot-water pipe-brooder system, has been changed to the individual-lamp-brooder system, and is now being extended to a total length of 400 feet. This is divided into pens 4 feet wide by 10 feet long, each pen having its separate brooder and being capable of accommodating 50 to 75 chicks, making a chick-capacity of 5,000 to 7,500 head in the one house. In addition to this, there are a score of outdoor brooders and as many more colony brooder houses, the total chick-capacity of the farm being 8,000 to 10,000 head.

A Maine example.

A very different type of poultry-farm, planned for wholly different conditions and located in a

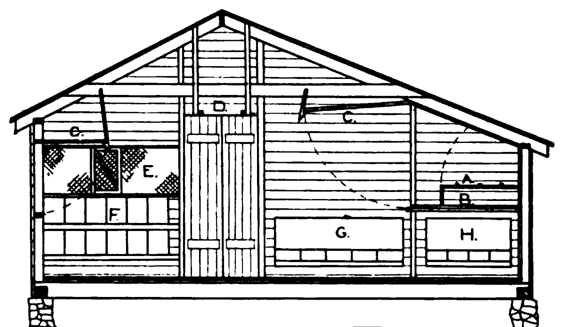


Fig. 197. Cross-section of poultry-house, showing details. "Go-well Poultry-Farm," Orono, Maine.—A, roosts; B, roost platform, floor of roosting-closet; C, C, swinging curtains; D, swinging doors between pens; E, broody coops—one in each end of pens; F, nest-boxes,—twelve in each end of pens; G, food hopper; H, grit, shells and charcoal hoppers.

very much colder climate, is the "Go-well Poultry-Farm," Orono, Maine. Here, the 2,000 laying stock is all housed under one roof, the poultry-house being 400 feet long by 20 feet wide and divided by board partitions (Fig. 197) into pens 20 x 20 feet each; 100 head of Barred Plymouth Rock pullets is kept in each pen. This house is most substantially built, with double board floor throughout, strongly timbered and solid-boarded, and both roof and walls shingled with heavy sheathing paper beneath the shingles all over. The total cost of the house was $2,700. This low cost is eloquent of the advantage of being in the lumber region, where there are great mills near at hand.

This poultry-house is the result of much experiment and observation, and is planned to minimize the labor while giving the maximum of results. It is lifted a foot and a half to two feet above the ground by a wall of cobblestones, has a double-pitch roof, the apex of the roof being half way between the front of the roosting-closet and the house front. A hand-car track is suspended from the roof, and all the doors swing both ways, allowing the car of food or water to be pushed along from pen to pen the entire length of the house. This labor-saving arrangement, together with the gain of feeding at convenience by the hopper-feeding method, enables one man to do all the work of feeding and caring for 2,000 layers.

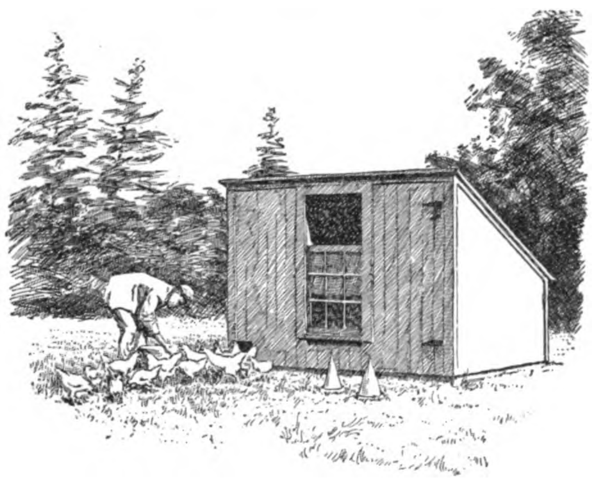


Fig. 198. One form of colony house for chickens.

In this house is illustrated the advanced type of fresh-air construction. It is located very nearly up to 45 degrees north latitude, and yet the birds housed in it have nothing but two cloth curtains between them and all-outdoors in that very cold climate. The front of each pen is boarded up for a length of two and a half feet at each end, and the whole front is boarded up three feet from the floor; a cloth curtain, tacked to a swinging frame hinged at the top, and two windows to give light on days when it is so stormy the curtains cannot be raised, make the remainder of the pen-front. The roosting-closet is raised three feet from the floor, making the whole floor of the pen available for exercise. The roosting-closet has a double board floor, is double boarded all about, the rear wall and roof being tightly packed with planer shavings, and the entire front is closed by a swinging curtain, tacked to a frame which is hinged to the roof. The front of the house is high, and the windows and curtained space set high, in order that the sunlight may reach the extreme rear of the floor in the colder days of winter when the sun is low in the south. Along the front, below the curtain opening, is a slatted front food-hopper filled with a mixture of dry meals and beef scraps, and at each end are hoppers for crushed shells, grit and charcoal, which are accessible to the fowls at all times. The floors of the pens are covered in winter with scratching litter of straw or swale hay, and on this litter a feed of dry grain is thrown twice a day; a half-barrel tub of cut clover-hay is supplied to each pen daily. The pullets put in this house late in the fall do not go out of it till the ground is fully dry in the spring; and here we find four square feet of floor space per bird, with the other conditions made right, ample for a sojourn of about six months, and the excellent health of the birds is proved by the eminently satisfactory egg-yield.

There is a plank walk three and a half feet wide and elevated about five feet from the ground, the entire length of the house in front. There are two yards, each 100 feet long by 20 feet wide, for each pen; one set of yards is north of the house and the other south of it. When the south yards become fouled by the accumulated droppings, the fences are lifted, the soil plowed, and a crop of some kind grown to disinfect it; and vice versa.

There are also 30 colony houses, each 7 x 12 feet in size, 5 feet high in front by 4 feet high at the back; these are used as brooder houses in the spring, two brooders with fifty to sixty chicks each being put in a house. When the chicks are large enough to wean from the brooders, the brooders are taken out, the chicks being left to grow to maturity in the houses, excepting that the cockerels are killed for market when of broiler size. These colony brooder houses are set on runners and can be drawn from one place to another. In midsummer they are placed with the back to the south and are blocked up to a height of about a foot, so that there is good shade and protection from the heat of the sun, both inside and beneath them.

Estimate.

In the incubator cellar at Go-well Poultry-Farm, beneath the barn, there are twenty 360-egg incubators. At the price of $30 each, these incubators cost $600. Sixty indoor brooders would cost $480, and thirty colony houses $600. The poultry-house for 2,000 head of stock cost $2,700. This amounts to $4,380, and leaves $620 for other appliances and tools, bringing the cost of all houses and equipment on this 2,000-head poultry-farm at $2.50 per bird. The cost of the 128-foot houses at Lakewood farm, including yard fences and everything complete, was $600 each, and they carry 400 head of layers each. Estimating that the cost of incubators, brooders and other tools and appliances would be about $1 per head of laying stock, we again have $2.50 per head as the capital required to well-equip a poultry-farm.

Since farms themselves vary greatly in price, depending on size, value of the land, value of the dwelling house and farm buildings, location and numerous other factors, it is obviously impossible to do more than estimate the amount of capital required for the farm itself. As the cost of Lakewood Farm is included in the total of capital invested, and that total is, in round numbers, $14,000, we have a capital of $3.66⅔ per head of laying stock; and it is reasonable to assume that $4 per head is a fair estimate of the capital required for land and equipment for a poultry-farm.

CAPITAL REQUIRED FOR A CALIFORNIA POULTRY-FARM, WITH DISCUSSION OF SYSTEMS OF ORGANIZATION.

By *M. E. Jaffa*

In California there are two different methods of conducting poultry-farms,—the colony plan, where a large number of fowls of different ages run together, and the intensive system, where the fowls are separated into small flocks, each having a separate house and yard. The advantages of the latter method are too numerous to explain in a short article, but chief among them are that different ages are kept apart, and those that have outlived their usefulness can be disposed of; disease can be controlled and the spread prevented; and trap nests can be used with more effectiveness. The colony plan does not, nor will it ever, conduce to systematic and highly progressive poultry-culture; such can be attained only by the intensive plan, and statistics fully bear out the statement. It would be far better to describe what a typical poultry-farm for California should be than to describe a typical California poultry-farm.

California is exceptionally well-favored for profitable poultry-raising both as regards markets and climate, there being very few days when the fowls can not be in the yard.

The fowl commonly used for commercial purposes in this state is the White Leghorn, and there seem to be good reasons why this should be so, for by proper care and judicious feeding the hens can be made to lay before they are six months old, and the size of the egg, under such conditions, will satisfy the most critical. This breed eats less than many others whose laying qualities are about the same.

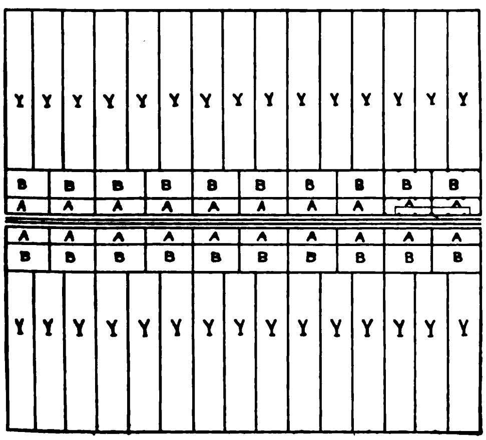


Fig. 199. Plan for a poultry-house.—A, compartments for roosts and nests; B, scratching-sheds; Y, yards.

The estimate.

A flock of 1,000 White Leghorns from a good laying strain should net at least $1,200 per annum. The estimated cost of a plant, irrespective of land, in accordance with the intensive plan, is as follows:

House for 1,000 laying hens, as per accompanying plan and description	$1,250 00	
Combined brooder and incubator house, with a capacity of about 600 chicks at one time	250 00	
Store- and feed-house	100 00	
House of four rooms, kitchen and bathroom	750 00	
Barn	250 00	
Water-supply and incidentals	250 00	
		$2,850 00
Horse and wagon	$150 00	
Tools, etc.	100 00	
Incubators (two), capacity 325 each	70 00	
Eggs, $5 per 100	50 00	
		$370 00
		$3,220 00

Land can be purchased at $50 to $100 per acre, but if near any of the large centers the price will be higher. From this estimate it would appear that about $3,500 would be sufficient to start such a plant. The amount of land necessary for the above plant is very small, not exceeding two acres. If, however, it is desired to raise crops,—and alfalfa is of inestimable value in feeding,—then more acreage will be required, the size of the farm in that case depending on the ideas and financial condition of the prospective poultryman.

Longhouse method.

It is true that the intensive method can be practiced by having a separate house for each yard; but it does not seem to the writer that such a plan is as convenient as one long house (indicated in Fig. 199). By the longhouse method one man can accomplish more in less time than by working under any other system. In inclement weather the attendant is under cover the entire time required for feeding, cleaning houses or gathering eggs. The roosts receive an adequate supply of sunshine and air by means of the skylights in each section. The house itself can be kept in a perfectly sanitary condition by frequent cleaning of the dropping boards and applying thin crude oil, or 28° distillate, to them and to the roosts. The nest-boxes, being of sheet iron and having no solder, can be thoroughly cleaned by heat. It will be seen from the plan (Fig. 199) that three yards are provided for two pens; the object of this is to have an alternate yard for each flock while the regular yard is being turned over and cleansed.

While the initial outlay for such a plant is greater than the cost of the commonly prevalent colony system, the fact that one man can care for more fowls, or for the same number with far less labor, will fully compensate for the difference. Aside from these considerations, it must not be forgotten that a much smaller piece of land will serve the same purpose.

In Fig. 201 is shown the perspective elevation of the proposed poultry-house and yard for the accommodation of 1,000 laying hens. It is taken in part from the plan adopted by the Must Hatch Incubator Company, of Petaluma, California. The dimensions of the house are: length 150 feet, width 32 feet, height at center 11 feet 4 inches, and at end of scratching-shed 6 feet. The house is divided in the center by an alley-way four feet wide, the two sides being symmetrical and each consisting of ten sections 15 feet by 14 feet. The length, 14 feet, is subdivided into the enclosure containing roosts and nests and the scratching-shed. The floor of the entire part under cover, 32 feet by 150 feet, consists of concrete, with smooth surface, which should extend about six inches beyond the scratching-sheds and have a slight fall from the house to the yard. The advantage of such a foundation is self-evident. Between the scratching-shed and the yard is a twelve-inch base-board, and similarly at the other end of this compartment. The yards are separated from the house by wire fence panels, each about five feet wide. Two of these on each section should be movable, either by means of hinges or by sliding. In inclement weather these panels can be covered with canvas or burlap. In California there would be no covering required for at least eight months in the year. It is very necessary that there should be adjustable panels, in order that the fowls may be kept in the desired yard.

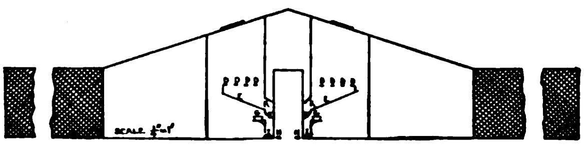


Fig. 200. Elevation of a long poultry-house.—D, D, D, D, roosts; E, E, droppings board; F, F, door for gathering eggs; G, G, nest-boxes; H, H, car rails; I, I, feeding troughs; K, K, door for cleaning droppings board.

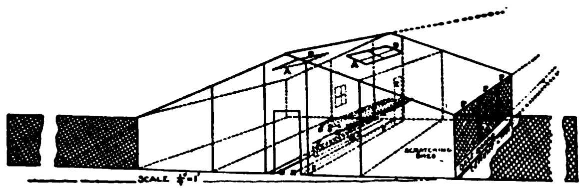


Fig. 201. Perspective of Fig. 200, showing a long poultry-house.—A and B, hinged skylight; C, door; D, roosts; E, dropings board; F, door for gathering eggs; G, nest-boxes; H, car rails; I, feed trough.

The fencing for the yards can be made from six-foot wire of two-inch mesh, with a twelve-inch base-board, or from four-foot wire of two-inch mesh, and then eighteen-inch wire of two-inch mesh properly supported at an angle with the four-foot fence. The latter style of fencing is somewhat more expensive, but tends better to prevent the hens from flying out of their respective confines.

The nest-boxes are movable and made in sets of six. They can be best constructed from galvanized sheet iron. Such sets are for sale at very reasonable figures. Wood may also be used for nests, but it does not possess the advantages of the metal. As the fowls have to pass through the scratching-shed to get to the nests, their feet will be comparatively clean and dry and no dirty eggs will be found.

A narrow hinged door in the alley, at the height of the nest-boxes, greatly facilitates the gathering of the eggs. A similar arrangement at the level of the lower end of the dropping-board admits of the droppings being removed easily and rapidly.

The troubles and inconveniences ordinarily met with in feeding fowls in bad weather are entirely done away with by operating under this system. The feed- and store-room can be attached very properly to the main house, or one section can be devoted to such purposes. The mash or soft feed is made up and fed, by means of the car, into the troughs, without the feeder being obliged to leave the house.

The feeding trough can be constructed of cement, where indicated in the figure. There are two long stationary troughs in the alley-way, one on each side. This would seem to be the most convenient way. Separate wooden troughs may be made for each section if so desired. There are several desirable troughs for sale that can be filled and cleaned very easily, and which do not allow the hens to get their feet inside. It might be stated that a practical man could make serviceable feeding troughs very easily and cheaply.

Water can be piped conveniently to the partition between every two sections to facilitate watering the fowls. Each yard should have a separate drinking fountain. This point requires special emphasis, that infection may not be carried from one yard to another. There are several suitable styles of drinking fountains on the market; but those which do not permit of being cleaned easily and fully should not be used.

An advantage of the system in question not to be lost sight of is that the poultryman, after the fowls have gone to roost, can sprinkle in the straw of the scratching-shed the grain for the morning feeding, and thus obviate the early rising necessary for the proper feeding of fowls. The mash can be fed in the afternoon, which is generally more convenient than in the early morning, particularly in winter.

The dimensions of the yard (Fig. 199), ten feet by fifty feet, may be considered somewhat small, but in view of the fact that there is an alternate yard which admits of the main one being dug up and purified, no trouble need be anticipated. The length, however, may be increased to suit the fancies of the individual. A shade tree should be planted in each yard, or one tree may serve for two yards.

If it is deemed desirable to start with a less number of fowls than is provided for by the plan here given, the size of the main house can be scaled to meet the requirements of the smaller flock; and additional sections can be built to the main house as the increase of the business warrants. It can readily be seen that a man's income may be doubled without correspondingly increasing the capital invested. It is better, however, to learn the business on a small scale and enlarge slowly, being sure of each step.

THE EQUIPMENT AND CAPITAL REQUIRED FOR PLANTING AND DEVELOPING AN ORCHARD.

By *Ralph S. Eaton*

Conditions vary so much in different localities that it is impossible to give definite statements in regard to the equipment and capital required for developing an orchard that will have general application. The statements and figures given below are based entirely on the writer's own experience in Nova Scotia. These will vary widely with different growers, depending on the management and the ability of the overseer to make men work intelligently and carefully, and also with the kind of fruit-growing and the locality.

The land.

In Nova Scotia, the value of land suitable for an orchard varies from $10 to $100 per acre. In selecting a site at a convenient distance from a country town, a choice could be made between wooded blocks of spruce and fir, twenty to forty years old, at a cost of $20 per acre; fields in pasture recently brought in from woodland, at a cost

Fig. 202. Baldwin apple tree (twenty-two barrels for 1904 and 1905). Kentville, Nova Scotia. (Ralph S. Eaton.)

of $30 to $40 per acre; and fields in a good state of cultivation, at $100 per acre.

The wooded land might give sufficient net returns in cord-wood and fence-rails to cover the first cost, while the expense of converting it into an easily cultivated field might make its ultimate cost equal to the highest-priced land. The probabilities are that reclaiming the new land would be cheaper. It might be better, under some conditions, for the chopping and disposing of wood to be done

Fig. 203. A good Ben Davis apple tree for Nova Scotia, at the age to begin to bear profitably.

by contract. The difference in the cost of plowing the pasture-field as compared with the older cultivated field, and the removal of stones and roots which are usually plentiful in new land, might bring the cost of this field quite up to the older cultivated field. Average conditions would be in favor of the pasture-field.

If gaining time in the growth of trees is an object, the wooded land, cleared and brush burned, could be planted at once, the trees set among the stumps, removing only those which would interfere. Few persons would be inclined to plant trees in such crude quarters, and the writer would hesitate to recommend this plan had he not had the experience of growing twenty acres of his orchard in this way for four years, and receiving the verdict of the public that there were no better trees to be found of the same age planted in the best cultivated orchards.

If one wishes to economize in the purchase of trees, and also to get the land free of stumps before planting, 1,000 root-grafts of apple could be purchased at a cost of $5 to $10, and grown in a nursery for three or four years. A sufficient number of first-class trees should then be available to set out ten acres of orchard, and the stumps would be in a condition to be removed easily.

In the case of the pasture-land, a saving of capital and annual expenditure might be made for a few years, if one is simply planting apple trees, and about forty to the acre, or two rods apart, by planting the trees without plowing around them, using thorough mulching or hand cultivation with shovel or fork, as would be the method of treating the trees in the stump land. This treatment might apply with equal economy to the highest-priced land, if crops of hay are taken for a few years from the large areas between the trees.

Fertilizers.

The question of fertilizing an orchard is always an important one and a large item of expense. The quality of natural manures is variable and the supply limited. The quality of commercial fertilizers is very uniform and the supply not limited. Though a more soluble fertilizer than ground bone might be preferred for young trees, and one with a larger proportion of nitrogen, perhaps more ground bone is used for young orchards than mixed fertilizers. An application of potash should be made as soon as trees begin fruiting. A liberal application to young trees, as indicated in the given estimates, would be a pound for each tree when planted, and an increase of one pound per tree up to twenty years.

Fig. 204. The result of good equipment. Clean tillage and low heading of peaches. (Michigan "peach belt.")

The estimates.

In addition to the original cost of land, the following is an approximate estimate for growing apple trees for the first three years on a ten-acre block, under any of the above conditions:

First year—		
400 apple trees, at 20 cts.	$80 00	
Planting, 5 cts. per tree	20 00	
Fertilizing—1 lb. bone per tree, 400 lbs. at 1½ cts.	6 00	
Applying fertilizer	50	
Cultivation with shovel or fork once each week, ten weeks	12 50	
Cost and application of tarred paper to protect from mice	5 00	
		$124 00
Second year—		
Replacing dead trees	$2 50	
Fertilizing 400 trees, 2 lbs. per tree	12 00	
Applying fertilizer	1 00	
Cultivation by hand ten times	15 00	
Removing tarred paper in spring and replacing in autumn	2 00	
		$32 50
Third year—		
Pruning	$3 00	
Fertilizing, 3 lbs. per tree	18 00	
Applying fertilizer	1 25	
Cultivation by hand ten times	20 00	
Removing tarred paper in spring and replacing in autumn	2 00	
		$44 25
Total for three years		$200 75

In some localities and conditions, an added allowance should be made for fencing.

At the end of the third year the cost of removing the stumps from the unbroken land would present itself. A strip of land on either side of the rows of trees, the width of a harrow, or about six feet, may first be cleared of stumps at an expense of $100 to $150 for the ten-acre block. The first plowing and removal of stones and roots would exceed the expense of plowing a similar area around trees in the cleared field by $100 to $150. Thereafter for five years, the expense of cultivation would be practically the same in all fields, when again $100 to $200 would probably be required to complete the clearing of the stump land.

The expense of caring for the ten-acre block from the fourth to the seventh year may be estimated as follows:

Fourth year—		
Pruning	$4 00	
Fertilizing, 4 lbs. bone per tree	24 00	
Applying fertilizer	1 50	
Plowing six feet on both sides of rows	20 00	
Harrowing ten times	18 00	
Hand work	2 00	
		$69 50
Fifth year—		
Pruning	$5 00	
Fertilizing, 5 lbs. per tree	30 00	
Applying fertilizer	2 00	
Plowing	20 00	
Harrowing ten times	18 00	
Hand work	3 00	
		$78 00
Sixth year—		
Pruning	$6 00	
Fertilizing, 6 lbs. per tree	36 00	
Applying fertilizer	2 50	
Plowing	20 00	
Harrowing ten times	18 00	
Hand work	4 00	
		$86 50
Total, fourth, fifth and sixth years		$234 00
Care first three years		200 75
Total for six years' care		$434 75

From the seventh to the twelfth years, one might expect, with such careful treatment, very liberal returns, though an orchard of this age can not be depended on for regular crops. In the above estimate the fertilizing and cultivating are quite double that which the average young orchard receives.

A more intensive system.

If one is developing a ten-acre field into a fruit farm, the system of planting forty apple trees to the acre would probably not be sufficiently intensive to satisfy the grower looking for fruit at the earliest possible period and for the maximum returns per acre. The interplanting of fillers of plums, pears, cherries, or early-fruiting varieties of apples, to the number of one hundred and twenty or more per acre, would strongly appeal to him. The writer has planted almost all of his orchards at the rate of three hundred and twenty trees per acre, rows sixteen and one-half feet apart, and trees eight and a half feet apart in the rows. In an orchard of twenty acres, planted in this way, the writer had a man with horse and cultivator stir the soil thoroughly around the trees one day of each week for eight to ten weeks for the first three years. It will be seen that this was much cheaper cultivation than that given in the estimate.

The land for trees planted one hundred and sixty to the acre should be plowed before the trees are set. The use of the subsoil plow is to be recommended.

The following estimate will apply to the more intensive planting:

Plowing 10 acres, at $2 per acre .	$20 00	
Subsoiling at $2 per acre	20 00	
Forty standard apple trees per acre, 400 trees at 20 cts. each . . .	80 00	
120 fillers per acre of plum, dwarf pear, acid cherry, or early-fruiting apples, at 25 cts. per tree .	300 00	
Planting 1,600 trees, at 5 cts. per tree	80 00	
Fertilizing 1,600 trees, 1 lb. per tree, at 1½ cts. per lb.	24 00	
Applying fertilizer	2 00	
Cultivating with horse and cultivator, once each week for 10 weeks, at $1.50 each cultivation	15 00	
Hand work around trees with hoe .	2 00	
		$543 00
Second year—		
Replacing dead trees	$15 00	
Fertilizing 1,600 trees, 2 lbs. per tree	48 00	
Applying fertilizer	2 50	
Cultivation with cultivator ten times at $1.50	15 00	
Hand work with hoe	2 00	
		$82 50
Third year—		
Pruning	$5 00	
Fertilizing 1,600 trees, 3 lbs. per tree, 4,800 lbs., at 1½ cts. per lb.	72 00	
Applying fertilizer	3 00	
Cultivation with cultivator ten times	15 00	
Hand work	2 00	
		$97 00
Fourth year—		
Pruning	$7 00	
Fertilizing 1,600 trees, 4 lbs. per tree	96 00	
Cultivating ten times with spring-tooth or Acme harrow	15 00	
Hand work	2 00	
		$120 00
Total for four years		$842 50

In all investments, interest should be taken into account.

General care.

The fruiting period for the fillers will have come by the fourth and fifth years, and a little more equipment will be necessary. One good all-purpose 1100-pound horse will have been sufficient, and will still answer for a number of years. For all general work, and especially for spraying and handling apples, the low crank-axle wagon will be useful. Those who do not possess one do not realize its labor-saving merits. For handling small-fruits, the express wagon is desirable; for removal of loose stone or small limbs a horse-cart is most convenient. To have clean trees and perfect fruit, one must have a spraying outfit consisting of a one-hundred-gallon

Fig. 205. Effective one-horse spraying outfit. This is as efficient as many of the two-horse rigs, and handier, especially for trees not very high. (R. S. Eaton.)

hogshead or tank, a good pump, two lines of twenty-foot hose, extension rods and nozzles. Power pumps are now often used for larger orchards.

The disc harrow is indispensable. The disc and spring-tooth harrows are the only implements for cultivation used in some Nova Scotia orchards, even when cover-crops are turned under.

The pruning for the first few years may be done with a good jack-knife. The pruning clippers, with handles about two feet long, are better than the saw while the pruning can be done from the ground.

Expense for storage depends on what room one may already have. The carriage-house makes a good place for the sorting of summer and autumn fruits, if a fruit-house is not available.

Fig. 206. Spraying outfit that may be used in orchards of forty acres or less.

If the winter varieties of apples are to be disposed of in November, no special cellar room for these will be necessary. However, if these varieties are to be shipped at intervals during winter,

Fig. 207. Spraying outfit for a small orchard.

frost-proof accommodation is necessary at the house cellar or apple warehouse on the line of railway. The latter is preferable when convenient, and often saves risk of frost in shipping and capital expenditure in building a cellar.

Summary.

To sum up, then, the necessary equipment for working a ten-acre orchard, the following inventory might be given:

Horse	$150 00
Working harnesses	45 00
Cultivator	7 00
Plow	15 00
Disc harrow	25 00
Spring-tooth harrow	15 00
Dray wagon, for single horse	50 00
Express wagon	75 00
Horse-cart	50 00
Spraying outfit	50 00
Pruning equipment	5 00
Ladders, baskets, etc.	12 00
Shovels, hoes, etc.	5 00
	$504 00

The writer has recently secured estimates of returns from a number of orchards in Nova Scotia that show, perhaps to the surprise of careless book-keepers, that well-kept bearing orchards have paid on an average during the past five years a net profit of 15 to 20 per cent on a valuation of $1,000 per acre.

Fig. 208. Clearing a rocky New England farm preparatory to planting an orchard. The trees will be set as soon as the rocks are cleared for rows.

COST OF ESTABLISHING AND MAINTAINING AN ORCHARD IN NEW ENGLAND

By *J. H. Hale*

There can be no standard of cost in the establishing of an American fruit orchard, as so much depends on the condition of the land at the start, and the general character of the soil and thoroughness of methods of preparation, planting and culture. Estimates of cost are so much at variance, that the actual five years' record of 100 acres of a rocky New England hill farm (Figs. 208, 209) of apples and peaches (planted 15 x 15 feet, one apple to each three peach trees) furnishes the solid facts which perhaps will serve as a basis of computation under average American conditions better than could be secured in any other way, as the law of averages is likely to obtain the country over where first-class orchards are established.

The 100-acre orchard here indicated was developed the first five years, or up to the first fruitage of peaches, by the work of only four cheap horses, when eight were really needed for best results. No spraying was required, and poor buildings were made to answer. Owing to the natural high state of fertility of the land, it was unnecessary to

Fig. 209. Rough land now five years under cultivation, on a rocky New England fruit-farm.

expend any large sum for fertilizers; so that any excess expenses appearing in other directions are more than met by such saving.

The original cost of the land, with very poor house and barn, was $2,447.90. The expenses were divided as follows:

First year—	
Repairs to buildings	$145 36
Four horses	400 00
Feed, etc.	232 05
Tools and repairs	93 19
Labor	823 16
Taxes	36 09
Second year—	
Trees	$667 63
Fertilizers	59 17
Labor	849 49
Tools and implements	175 27
Grain and feed	99 10
Miscellaneous, including taxes	113 14

Third year—	
Labor	$821 39
Fertilizers	241 58
Tools and implements	45 30
Grain and feed	298 10
Miscellaneous, including taxes	109 40
Fourth year—	
Labor	$1,893 19
Hay and grain	425 02
Fertilizers	207 82
Tools and implements	259 34
Buildings and repairs	434 15
Trees	282 40
Miscellaneous, including taxes	96 45
Fifth year—	
Labor	$1,038 42
Hay and grain	493 76
Fertilizers	184 20
Tools and implements	174 98
Clover seed	56 46
Buildings and repairs	153 55
Telephone construction	100 00
Miscellaneous	357 94

Total expenses for five years as follows:

Original land cost	$2,447 90
Buildings and repairs	733 06
Tools and implements	748 08
Labor	5,425 65
Horses	400 00
Hay and grain	1,548 03
Fertilizers	692 77
Clover seed	56 46
Telephone	100 00
Trees	950 03
Miscellaneous and taxes	713 02
	$13,815 00

The figures for the second five years of this orchard, which is now eleven years old, are also available; but, as they are so closely interwoven with crop expenses, they are difficult to analyze. It may be added, however, that there was no expense for trees, and the bills for tools and implements were much less, while some $500 per year must be added for spraying. All the other expenses run much the same as for the first five years, or practically $27,000 for the first ten years' development of a 100-acre apple orchard on rough stony land. The net peach income from the interplanted trees, however, paid about half of this expense, leaving the net cost of the apple orchard about $13,500.

CAPITAL REQUIRED FOR AN IRRIGATED FRUIT-FARM. (COLORADO EXPERIENCE.)

By *W. F. Crowley* and *J. H. Crowley*

Many successful and profitable fruit-farms comprise 160 to 1,000 acres each. The tendency in the West is very much toward big things. However, the best returns per acre, the large yields that are cited to prove the productiveness of the soil in certain sections, or the profits to be derived from land investments are, as a rule, secured by those farmers on small tracts who are giving close attention to the business.

Size of establishment.

In some districts, irrigated peach and apple orchards have sold as high as $1,000 to $1,500 per acre. These prices have usually been based on the earning capacity of the orchards in those districts. Where such favorable conditions exist, the writers have observed that the average size of the fruit-farms is five to ten acres. In such districts, the home-seeker who desires to invest in a fruit-farm from which paying crops can be taken at once, will find the question of capital and equipment a very simple one indeed. He can buy a ten-acre orchard with house, stable, and such tools as may be needed at prices from $6,000 to $12,000; and not more than $500 additional will

Fig. 210. An irrigated orchard. Dark streaks on each side of furrow show how water soaks on red clay and gravel lands of the western slopes.

be required to carry him through the first season until crop returns are in, after which all should be clear sailing,—provided, always, that he has made no mistake in the selection of his location or choice of varieties of fruits.

When the orchards are all small and a great number of them in the vicinity of a shipping point, the custom is to form a coöperative shipping association. This association employs a competent marketing man as manager, and builds packing sheds, storage cellars and warehouse, for handling and shipping the entire crop of its members. In some cases the packing is done at the headquarters and under the supervision of the association manager. This simplifies matters to a large extent, and requires a smaller outlay for the individual grower in the way of packing and storage buildings on the farm; besides, it insures a uniform grade and pack of all fruit shipped by the association.

For the horticulturist who contemplates making an orchard for himself, the 40- or 80-acre farm can be developed with greatest economy, and will insure a large income from the money invested. A large farm, one of the latter size, affords an opportunity for speculation, as one-half of the place, when it comes into bearing, can often be sold for enough to pay the entire cost of the eighty acres of land and all improvements. The cost per acre will be no less on a larger tract than it will

Fig. 211. Young orchard with two furrows on each side of rows for irrigation. View on Ashenfelter ranch, Montrose, Colorado.

be on a place of forty to eighty acres, but on a smaller tract it will undoubtedly be proportionately more. The writers, therefore, have based their estimate of the equipment and capital required, on the forty-acre farm.

Estimates.

Peach, cherry, plum and prune trees come into bearing in one-half to two-thirds the time required for apple trees to return a full crop, and for that reason require a smaller investment. Nevertheless, apple trees being planted at greater distance apart give an opportunity to secure something from the growing of crops between rows during the first three or four years.

Mixed planting is not to be recommended. The plan, so much advocated a few years since, of setting apple trees the regular distance apart and filling in between with short-lived varieties or with peach trees, has not proved profitable in the irrigated West. The various fruits ripening at different seasons and requiring irrigation at different periods, do not give best results when planted in the same rows.

As a general proposition, the ideal commercial orchard will cost $100 to $150 per acre above the first cost of the land and water-right to bring it to full fruiting age. After counting the interest on money invested from the time of purchase of the land to the first paying crop, and allowing a reasonable amount for the risk in shipment, planting and growing of the trees for three to eight years, the writers conclude that an orchard of producing size that can be bought for $300 per acre is a better investment than starting with the raw land and building a place.

In the estimate that follows, $100 per acre has been allowed for the raw land and water-right. In many places, good fruit lands are obtainable for less money, but it pays to be sure of a good water-supply; and lands with a water-right such as can be depended on at all times can hardly be bought for less than the price named. It is also most important to select good land which is located not over four miles from a good shipping station. One to two miles is much better, and adds $25 to $50 to the value of each acre of orchard as compared with the longer haul.

Estimated Cost of Establishing a 40-acre Irrigated Fruit-Farm

First year—	
Forty acres of land, with perpetual water-right, at $100	$4,000 00
House, five or six rooms	1,000 00
Barn and outbuildings	500 00
Fences	100 00
One good team, mares or mules	250 00
One riding and driving horse	75 00
One milch cow	50 00
Hogs and poultry	25 00
One set double work harness	30 00
One set single work harness for furrowing	10 00
One set single buggy harness	13 00
One farm wagon	90 00
One spring wagon or buggy	75 00
One common 12-inch walking plow	12 00
One 8-inch diamond plow for work near trees	11 00
One single shovel furrowing plow	3 50
One two-section steel harrow	12 00
One disc harrow or riding cultivator	30 00
One single cultivator	7 50
Pruning tools, shovels, hoes, etc.	20 00
Trees and plants—	
Twenty acres apples, 70 trees to acre, 1,400 trees at 10 cents	140 00
Five acres peaches, 140 trees to acre, 700 trees at 6 cents	42 00
Two acres cherries, 140 trees to acre, 280 trees at 20 cents	56 00
One acre prunes, plums, apricots, 140 trees at 20 cents	28 00
One acre grapes, 900 vines at 3 cents.	27 00
One acre raspberries and blackberries, 1,000 canes at 1 cent	10 00
One acre gooseberries and currants, 1,000 bushes at 2 cents	20 00
One acre strawberries, 10,000 plants at $2.50	25 00
Total, 32 acres fruit.	
Five acres alfalfa; seed for same	10 00
Three acres garden and yards.	
Expense of operating first year—	
Plowing 40 acres at $1.25	50 00
Harrowing and dragging at 50 cents.	20 00
Furrowing ready to plant	20 00
Planting 20 acres apples at $3.50	70 00
Planting 8 acres stone fruits at $6	48 00
Planting 1 acre grapes	10 00
Planting 1 acre raspberries and blackberries	10 00
Planting 1 acre gooseberries and currants	10 00
Planting 1 acre strawberries	15 00
Making head laterals	20 00
Bridges, culverts and headgates	40 00
Cultivating 32 acres six times	96 00
Hoeing 28 acres twice	28 00
Hoeing 4 acres berries, etc., three times	24 00
Furrowing 32 acres for irrigation five times	64 00
Irrigating 40 acres five times (Strawberries will require more, and alfalfa less than five irrigations.)	100 00
Water assessments, maintenance of canal, 50 cents per acre	20 00
Taxes	25 00
Total outlay first year	$7,342 00

Plate XIV. Farm lands in tropical Florida. Coconut grove on Long Key

In this estimate of the first year's work, the writers have figured on the basis of hiring all the work done. If the owner does nothing more than oversee the work, his living expense for the time so occupied may be added; but assuming that he does much of the work himself, the saving of hired help will pay the living expense of himself and family. Therefore, the estimate as given will include all expense that could properly be charged to the investment. Further, no special allowance has been made for horse feed; but the estimated cost of plowing and cultivating covers these items in the early part of the season, while the five acres reserved for alfalfa and planted to oats with alfalfa the first year, will give sufficient feed to carry the stock through the remainder of the year. Land between tree rows will also help to supply live-stock and poultry, and to pay for contingencies which have not been provided for in the table of estimates.

Second year—	
Trees for replanting, 10 per cent of cost for first year	$34 80
Replanting	30 00
One deep plowing 28 acres at $1.25	35 00
Cultivating 32 acres six times	96 00
Hoeing 28 acres twice	28 00
Hoeing 4 acres three times	24 00
Irrigating 40 acres five times	100 00
Furrowing 32 acres five times	64 00
Cleaning out laterals in spring	20 00
Water assessments, maintenance canal.	20 00
Taxes	25 00
Repairs, fences, bridges and buildings	25 00
Pruning, lightly	32 00
Total expense second year	$533 80
Third year—	
Practically the same as second year (No charge for replanting, but a slight increase in expense of pruning and in general repairs.)	$533 80
Fourth year—	
General running expense same as above.	$533 80
Additional equipment, because of apple and peach trees coming into bearing:	
Spray pump and nozzles, hose, etc.	25 00
Spray tank	25 00
Trucks for spray outfit and for use in hauling fruit out of orchard	75 00
500 picking boxes at 14 cents	70 00
One dozen picking buckets	3 50
One extra team	250 00
One set double harness	30 00
Packing shed	200 00
Total for four years	$9,621 90

Fig. 212. Winesap orchard in bloom. Colorado.

This is a conservative and practical working estimate of the cost of producing a good irrigated fruit-farm. To give an accurate estimate of the returns that can reasonably be expected is a more difficult task. With such a selection of fruits as outlined above, a fair sum should be realized each year after the first season. The one acre of strawberries should return $200 to $500 the second season. Raspberries and blackberries should give as good results the third year. Grapes, currants and gooseberries should bring some money the third year and full crops thereafter. The fourth season should find all stone-fruits in bearing, and the total crop for that year will bring $1,000 to $2,500, according to the season, prices and other factors. After the fifth year some returns may be expected from the apple orchard, and the annual output of the farm should average $2,500 to $6,000. With an annual average gross income of $4,000, the expense for boxes, spray materials, cultivation, irrigation, pruning, packing and hauling the fruit to shipping station, may be counted at $2,000, leaving a net profit of $2,000, or 10 per cent interest on a valuation of $20,000, or $500 per acre.

Fig. 213. Peach tree before pruning. California.

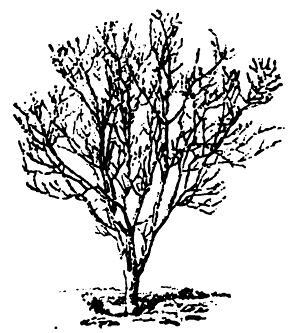


Fig. 214. Peach tree after pruning.

CAPITAL REQUIRED FOR ESTABLISHING AN UP-TO-DATE NURSERY OF GENERAL HARDY PRODUCTS.

By *P. J. Berckmans*

In this day of progress in all horticultural ventures, it is necessary that a man be able to meet successfully all competition in growing nursery stock of the highest standard of quality, and be able to grow it in such quantities as will allow a fair margin for its production. The prices for nursery products which have ruled during the past few years have usually been very low as compared with the cost of production. There are several factors which account for this. The main reason is that numberless small nurseries have come into existence without sufficient capital or knowledge of the business. After a few years of struggling they have gradually been compelled to relinquish their efforts, and the large quantity of inferior stock held by them has been placed on the market regardless of the price that could be secured. This flooding the market with inferior and cheap stock has caused a depression in the prices of nearly all nursery products offered by the leading growers. However, this depression of healthy conditions is gradually lessening by the rapid failure of this class of growers.

General considerations of organization.

Taking it for granted that the minimum size of an up-to-date nursery is 200 acres, as this quantity of land is necessary for growing a general line of nursery stock, we have the following considerations:

1. The cost of land must be counted as the first estimate. The price of land varies greatly according to location,—that is, proximity to a large city, or, more especially, easy access to transportation facilities. A fair estimate would be $50 to $100 per acre; but when lands are more or less remote from these requisites, their value may be computed at half of this, or even less. The amount of capital invested in land lies with the purchaser. The selection of the land depends somewhat on the kinds of trees or plants the nurseryman wishes to place on the market. It is obvious, also, that the particular trade to be supplied should be fully predetermined. If one intends to grow stock for the supply of a strictly local trade, the nursery should be located as near as possible to a large center of population, with the shortest distance for carrying products. But if a strictly wholesale trade for a few leading classes of fruit and ornamental trees is planned, then lands lying at a greater distance, but always near a railroad where the forwarding facilities are ample, may be used. The first cost of the land will vary accordingly. Nursery land should be of good quality, easy to work, naturally drained, or capable of being drained at small expense. The soil should be of different kinds in order that the different classes of trees and plants may be grown to the best advantage. Level lands are to be preferred, as rolling lands or hillsides are subject to washing, particularly in the South. To avoid this, such lands may require terracing, which adds much to the cost of preparation. It may not always be possible to secure a tract of 200 acres of land that has not been more or less depleted by faulty cultivation. Forest land of good quality may be found more profitable in this case; the expense of fitting it for the nursery must be added to the first cost. Frequently, however, the wood cut and sold from such land not only covers the cost of clearing, but a part of the purchase money also.

2. The labor must be considered. As the price of labor is rapidly increasing, and the competition in the nursery trade must be met, it is obvious that every possible labor-saving implement and condition must be utilized; and, to this end, the first preparation of land, before any planting is attempted, must be very thorough; the land must be free from stones, roots or other obstructions. The number of laborers required will depend on the facilities for working the land, and the products that are grown. Taking as a basis a tract of 200 acres of level land, free from obstructions, and of a loamy texture, ten to twelve mules or horses and a minimum of fifteen men would be required to cultivate the land and haul the products to a market or shipping point not above a distance of three miles; an increase of animals is needed for greater distances, especially during the shipping season, when an additional number of men may also be found necessary.

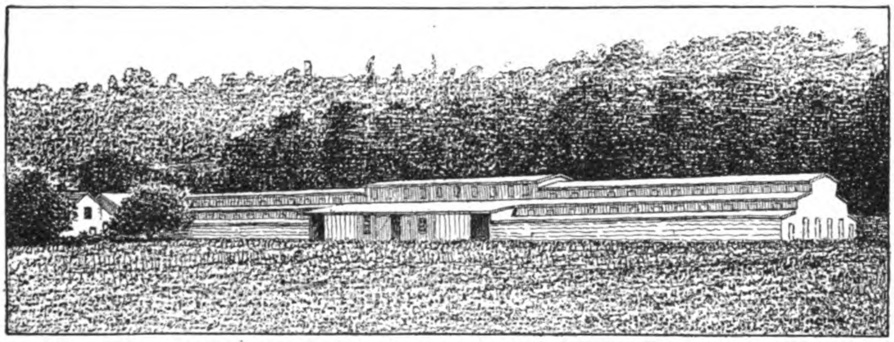


Fig. 215. Winter storage building on an Ontario nursery farm.

3. One must consider the question of fertilizers. This cost is very difficult to approximate because of the various classes of material and quality required. The condition of the land and the kind of products must be considered. Whenever good stable manure is obtainable, it is by far the best material for general nursery purposes, as its liberal application replaces the humus in which treed lands soon become deficient. Hauling and spreading stable manure is more expensive than the applying of commercial fertilizers. However, some commercial fertilizer, especially bone meal, should always be used as an adjunct to stable manure.

4. An estimate of the cost of the necessary buildings is given at the end of this article. The first cost must be governed by locality and facilities for construction. In the Middle States, the buildings, except the dwelling-houses, need not be so roomy or substantial as is required in northern sections, where storage is necessary (Fig. 215).

5. An abundant supply of water must always be

provided for use of the household, animals, irrigating the parts of the nursery used for raising seedlings, and for the packing-house. As the supply must depend on local facilities, whether well or stream, the cost of bringing it where needed by steam, gasoline, wind or other power, must be figured in the cost.

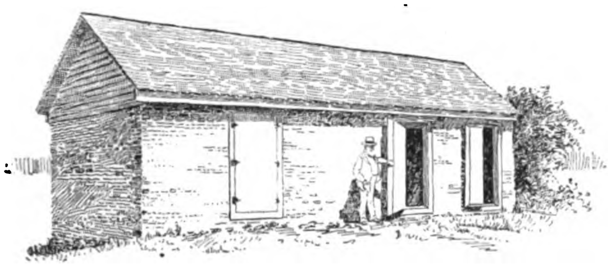


Fig. 216. Fumigation house, well-constructed and efficient, costing only $250 complete.

6. Facilities for fumigation must be provided. The nursery inspection laws in most states require that all products be fumigated by hydrocyanic acid gas before they can be sold or forwarded, and for that purpose a well-constructed fumigating house must be part of the equipment of every nursery. Wooden structures are seldom efficient and require frequent overhauling. A building constructed of brick or concrete, with heavy refrigerator doors and perfectly air- and gas-tight, is by far the cheapest and the most economical in operating. The illustration (Fig. 216) shows a well-constructed house that gives entire satisfaction. The house is 34 x 15 feet, with two compartments of 12 x 13 feet each; a smaller compartment of 3 x 5 feet for fumigating cuttings, buds or small quantities of trees, and another of 7 x 2½ feet for storing chemicals. Each of the larger compartments holds 2,000 to 5,000 trees of average size at each charge. The cost of this building, including thick refrigerator doors and ventilators, inside walls and ceiling, with two coats of plaster and one of carbon paint, and slat-floors, was only $250.

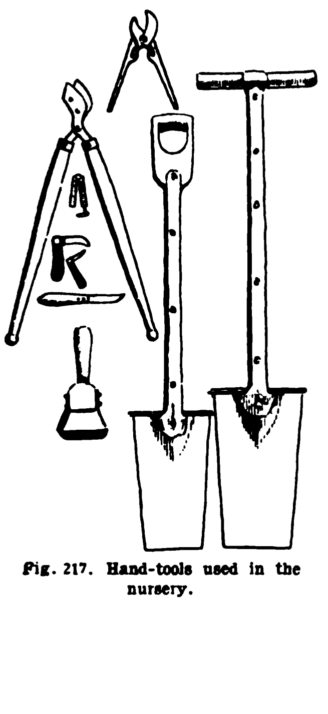


Fig. 217. Hand-tools used in the nursery.

7. The implements should be of the latest and most improved pattern. A partial list of those needed is given below.

8. Seeds, seedlings, trees and the like must be included. The first work in the equipment of a nursery is the planting of specimen orchards of such varieties of fruit and ornamental plants as it is intended to grow, in order to have types true to name from which grafts may be cut. The success and reputation of a nurseryman depends greatly on the genuineness of his products, and on this he can rely only if he knows that his stock trees and plants are correctly named. Show-grounds of evergreens, flowering shrubs and the like should be planted. In addition, sufficient quantities of fruit trees and ornamental-tree seedlings must be purchased for planting the different nursery blocks; this item may reach any sum from $5,000 to $15,-000, according to the kind of products to be grown.

9. Packing-house supplies must be provided, such as lumber, burlaps, moss, straw, nails and labels, and chemicals for fumigating.

10. A medium-sized propagating house, or well-constructed hotbeds, must be available for propagating by seed or cuttings.

11. Incidental expenses, taxes and insurance; these will be found to occur very frequently, and a sufficient sum must be apportioned.

12. Office fixtures and advertising must not be overlooked.

Estimates of capital.

In making the following estimates, a minimum average price for every item has been used, but

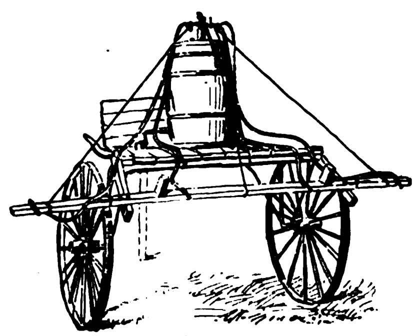


Fig. 218. A nursery spray-rig.

this must be altered according to locality. With fifty years' experience in the nursery business, the writer is satisfied that the total cost of establishlishing a first-class nursery of 200 acres, equipping it as it should be, would not vary greatly from the sum indicated in the recapitulation, viz., in round numbers about $35,000.

RECAPITULATION

1. Cost of land, 200 acres, minimum $25 per acre	$5,000 00
2. Labor—foreman, $600; assistant foreman, $480; 15 men at $30 per month, $5,400; 10 mules or horses, $2,000; maintenance for one year at $8 per month, $960	9,440 00
Amount carried forward	$14,440 00

Amount brought forward	$14,440 00
3. Fertilizers	1,000 00
4. Buildings—Dwelling, $3,500; 6 laborers' cottages, $1,200; 2 dwellings for foremen, $800; barn, $200; stables for 10 horses or mules, race-track style, $500; wagon and implement shed, $200; packing house, $1,000; fumigating house, $250	7,650 00
5. Water—tank and tower, $250; gasoline engine, pump, piping, etc., $500	750 00
6. Fumigating—barrel pump, $40; bucket pump, $4; cyanide of potassium, sulfuric acid, lime, copper sulfate, sulfur, $100	144 00
7. Implements—4 two-horse wagons, $280; 1 two-horse wagon, $40; cart, $30; harness for above, $100; 4 two-horse plows, $32; 10 one-horse plows, $45; 10 cultivators, $40; 2 harrows, different, $50; cutaway harrow, $20; seed drill, $75; mowing machine, $45; horse-rake, $20; tree-digger, $40; hand tools, $60; repairs, $100; pruning and carpenter's tools, $50	1,027 00
8. Seeds, trees, seedlings, etc. This item may be estimated as high as $15,000, but minimum is	5,000 00
9. Packing house supplies	500 00
10. Propagating house, with heater, coldframes and sash, minimum	1,000 00
11. Taxes, incidentals, insurance	
12. Office expense—telephone, $36; stationery and supplies, $250; safe, $150; catalogues, $500; postage, $500; 3 desks, $75; typewriter, $100; chairs and stove, $75; library and periodicals, $100; clerk, $600; stenographer, $500; advertising, minimum, $500	3,386 00
Total	$34,897 00

EQUIPMENT FOR A GENERAL TRUCK-FARM

By *John W. Lloyd*

The capital required for starting a truck-farm will depend on its size and location and the particular crops to be grown. This article will consider a truck-farm in southern Illinois. In the principal trucking region of southern Illinois, the leading vegetable crops are tomatoes, cucumbers, gem melons, sweet-potatoes, asparagus and rhubarb, with string beans, spinach and winter onions holding places of minor importance. Although the accompanying estimate of the cost of equipping a truck-farm has reference to a particular region, it is applicable, in a general way, to other regions where the same crops are produced and similar methods of culture are practiced.

In the region under consideration, an eighty-acre farm with modest buildings, located on a good road, within three miles of a shipping point, can be purchased for about sixty dollars per acre. Probably twenty-five acres of the land would be suitable only for timber and pasture. Another ten acres might be left in meadow. This would leave forty-five acres to be plowed and cropped. The first year, twenty-five acres would be sufficient land to devote to the distinctively truck crops. The other twenty acres could be planted to corn and cowpeas.

The twenty-five acres devoted to truck crops might be divided as follows: 5 acres tomatoes, 2½ acres melons, 2½ acres cucumbers, 10 acres sweet-potatoes, 2 acres asparagus, 2 acres rhubarb, 1 acre string beans. One acre of winter onions and 1½ acres of spinach could be planted in the fall on the land occupied by melons earlier in the season.

For starting the tomato, melon, cucumber and sweet-potato plants, two fire hotbeds, each one hundred feet long by six feet wide, would be needed. This is assuming that the tomato plants are to be shifted to coldframes when the hotbeds are needed for starting the melons and cucumbers, and that the bedding of the sweet-potatoes is to be deferred until after the melons and cucumbers are transplanted into the field. Otherwise, more beds would be needed. The two beds will hold approximately ninety-six hundred tomato plants set four inches apart each way. This number will be sufficient to plant the five acres, and allow 10 per cent extra for replanting, provided the plants are placed five feet apart each way in the field. Forty-eight hundred hills of melons can be started in "dirt bands," or bottomless boxes, in one bed, and the same number of cucumbers in the other. This again allows 10 per cent for replanting. Fifty bushels of sweet-potatoes can be bedded in the two beds, and will furnish enough plants at the first pulling to set the ten acres.

For carrying the tomato plants after they are shifted from the hotbeds, four coldframes, each one hundred feet long and six feet wide, would be needed. This would allow the tomato plants to be set nearly six inches apart each way.

The cost of materials for the hotbeds and coldframes would be as follows: 3,000 feet lumber, $75; 8 loads flag-stones, $8; 66 hotbed sash, $165; 267 yards canvas, $21.36; 10,000 dirt bands for melons and cucumbers, $10; total, $279.36.

To cultivate properly the area under consideration and to haul the products to the shipping point, two teams of horses or mules would be required. It would pay to invest about $500 in the two teams.

For hauling the manure, preparing the land, planting and caring for the crops, and transporting the products to the railroad station, the following equipment would be needed: 2 wagons, $120; 2 sets bolster springs, $14; 2 wagon covers, $12; set double harness, $34; set double harness (chain), $16; 2 twelve-inch breaking plows, $24; one-horse turning plow, $6.50; sweep, $3.50; disc harrow, $22; spike-tooth smoothing harrow, $11; double-shovel cultivator, $3.50; 2 five-shovel cultivators, $6.50; spike-tooth cultivator, $3.75; two-horse cultivator, $18; one-horse corn drill, $12; planker, $2; "boat," $1; 2 short single-trees, $1; 4 hoes, $1.60; 2 manure forks, $1.70; 2 shovels, $1.30; 4 spades, $2.60. Total expense for implements, $317.95.

The cost of the planker and "boat" refers merely to the material used in their construction, since it is assumed that these will be made on the place. For making these implements and for constructing the hotbeds and coldframes, as well as for other general use, a few carpenter's tools would be needed. These, including axes, saws, hammers, bits, and the like, may be roughly estimated at ten dollars.

For planting the forty-five acres with the crops and in the way specified, the following list of seeds and plants would be needed: 5 ounces tomato seed, $1; 2 pounds melon seed, $2; 2 pounds cucumber seed, $2; 50 bushels seed sweet-potatoes, $25; 11,000 asparagus roots, $44; 5,500 rhubarb roots, $44; 1 bushel seed beans, $7; 2 bushels seed corn, $3; 10 bushels cowpeas, $15. Total cost of seeds and plants, $143.

For manuring the melons and cucumbers in the hill, one full car-load (thirty tons) of manure would be required. Unless the land is fairly rich, the tomatoes also should be manured or fertilized in the hill; and the land on which the asparagus and rhubarb are to be planted should receive a dressing of manure. In all, no less than three car-loads should be used. This would have to be shipped in from St. Louis or Chicago, for the section under consideration, and would cost, including freight, approximately twenty dollars per car.

For handling properly the tomatoes, melons, cucumbers and beans at harvest time, at least two packing sheds would need to be constructed. These might be very rough, temporary affairs like the one shown in Fig. 219, or perhaps slightly more elaborate, though they are always comparatively simple in construction and usually temporary, since the truck patches are shifted to different parts of the farm from year to year. A modest yet well-built packing shed could be built from 400 feet of lumber. This would cost about $10, making the cost of the two sheds $20.

Fig. 219. A rough temporary packing shed in a tomato field. The load is ready to start for town. (Buncomb, Johnson county, Illinois.)

The labor would be a large item of expense on a place of the kind under consideration. Four men would be required to handle the work properly after the season opened in March, and additional help would be needed at the time of transplanting the various crops in the field and at the height of the picking season. Assuming that possession was secured in the fall, one man's time would be fully employed during the remainder of the autumn in the construction of hotbeds and hauling manure, and additional help would be needed in the latter operation because of the necessity of unloading cars promptly. Early in February the planting and care of the hotbeds would begin, so that it would be fair to figure on one man's being employed practically all the time from November 1 to March 1.

At the price of labor ruling in the locality under consideration, the expense for labor from November 1 until July 1—after which time the receipts from the sale of products would meet the current expenses—would be about as follows:

One man, November 1 to March 1, 4 months, at $25	$100 00
Extra help in autumn	50 00
Four men, March, April, May, June, at $25 per month	400 00
Extra help in transplanting, etc.	100 00
Total	$650 00

The only other large item of expense previous to the harvest would be the feeding of the teams, which may be estimated at about $150.

SUMMARY

80 acres land, with buildings	$4,800 00
Hotbeds and coldframes	279 36
Two teams horses	500 00
Implements and tools	327 95
Seeds and plants	143 00
Three car-loads manure	60 00
Lumber for packing sheds	20 00
Labor	650 00
Feed for teams	150 00
Total	$6,930 31

Other expenses will arise that it is impossible to foresee. A small estimate for these would be $69.69, making a total capital required of $7,000.

No provision has been made for baskets and crates, as these are usually purchased at the local factories as needed, and are paid for after the products are sold. Neither has a storage house for sweet-potatoes been considered. It would be advisable, for the first season at least, to hire storage space in a commercial plant.

CAPITAL REQUIRED FOR A MODERN INTENSIVE MARKET-GARDEN

By *Warren W. Rawson*

The first thing to consider is the location. This should not be over five miles from market. If the distance is more than five miles, only one trip a day can be made to market; whereas, if less, two trips can easily be made. Thus it would be cheaper to pay $500 per acre for a place within the above limit than to pay $100 per acre for a location further out. The saving in teaming and time of a man would more than pay the difference in interest and taxes.

Anothor important consideration in the selection of a location is the soil. This should be of a sandy nature, with a subsoil of yellow loam over sand. This character of soil is especially adapted to quick-growing crops. If there is a clay subsoil, the land is likely to be cold and will not drain quickly enough to grow early crops in either a wet or a dry season. If possible the land should have a southern slope, thus assuring earliness of crops and better adaptability to irrigation.

The location being chosen, the next thing is the necessary equipment to do a paying business. This article will consider a place of ten acres to cost $5,000 for the land and $5,000 more for the buildings, including house, stable and wash-shed. Then an additional $5,000 is required for three greenhouses, each to be 200 feet long and 30 feet wide. It would be impracticable to have less than three greenhouses because of the different temperatures required by the different crops. These crops may be limited to five, namely, cucumbers, radishes, lettuce, parsley and tomatoes. Taking into consideration the varied conditions that these crops require, it can readily be seen how little could be done with less glass area.

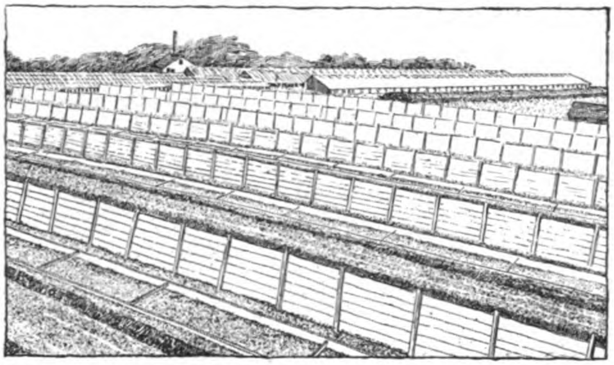


Fig. 220. A nest of hotbeds on a market-garden in Massachusetts.—Each row of beds is supplied with a windbreak fence. The greenhouses are shown beyond the hotbeds. (Warren W. Rawson.)

In addition to the houses, more or less hotbed sash will be required in the spring. The grower will need at least 400 sashes, at a cost of $2.50 each. Then the fences, mats, planks and shutters will cost about $2.50 for every sash, making a total of $2,000. Under these sashes are grown many crops, and they are especially valuable for the hardening-off of plants which have been started in the houses, transplanted to these beds, and later to be planted in the field. It would be impossible to do this work in the houses; thus it is seen what an important part the sashes take in the growing of many of the crops.

The irrigation outfit, one of the most important requirements, east as well as west, should be arranged to supply water to any part of the ten acres, including greenhouses, wash-shed, stable and dwelling-house. Of course, if the water could be supplied by the city or town in which the market-gardener is located, at a cost of not over ten cents per 1,000 gallons, it would be cheaper to have it thus supplied than to go to the expense of erecting tanks, windmill and steam pump, provided the water was naturally of easy access. But it would not be advisable for any one to buy a place where water is not easily accessible.

The piping of the place for irrigation should be done systematically. The mistake of laying too few pipes should be avoided, for it is much cheaper to lay pipe than to supply hose. The main pipes should be at least two and one-half inches in diameter and the cross pipes one and one-fourth inches. One-inch hose should be used for outside surface irrigation and two and one-half-inch hose for irrigating furrows.

For the ten-acre piece, using the sized pipe mentioned above, it would require 2,000 feet of two and one-half-inch pipe, 2,000 feet of one and one-fourth-inch pipe, 400 feet of one-inch hose, 300 feet of three-fourths-inch hose and 200 feet of two and one-half-inch hose. This quantity of pipe and hose with fittings connecting all departments would cost, all laid, about $1,000.

Four horses would be required, at a cost of $200 each; one two-horse and one one-horse market-wagon, $400; two tip-carts and one manure wagon, $300. A complete collection of all necessary machines and implements, using only the most modern, should also be added, at a cost of about $500.

Fertilizers and manure should be on hand early in the winter to be prepared for spring use. The manure should be turned over twice before the first of March, and the fertilizer should be mixed by that time in the proper proportion and be ready for use. If manure alone were used, it would take about twenty cords to the acre, which, at $5 per cord, would amount to $1,000. Also, if fertilizers alone were used the cost would be the same, as it would take about three tons to the acre, which at the average market price would be about $100 per acre.

Taking into consideration the cost of all the necessary requirements for the proper fitting up of a modern market-garden, using a ten-acre plant as a basis, the total would be as follows:

Land	$5,000	Total, $21,000
Buildings	5,000	
Greenhouses	5,000	
Sash, etc.	2,000	
Irrigation	1,000	
Horses	800	
Vehicles	700	
Tools	500	
Fertilizers	1,000	

In the above figures incidentals are not included, but these may be saved in some of the estimates, which are all given in round numbers. Neither has the cost of a driving horse and buggy or automobile for the owner been taken into consideration. He will have too much to do the first year or two to have time for either one of them.

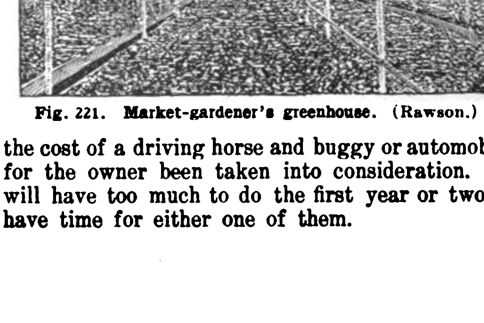


Fig. 221. Market-gardener's greenhouse. (Rawson.)

As to labor, it will require ten men in winter and twenty in summer to work a place of this size. Above all, to be successful, the man himself must know his business thoroughly, and be able to do any kind of work that is required on the place.

It can readily be seen, from a survey of the above estimates, that the expenses will be large; therefore good crops and good crops only must be grown to make the business pay. The taxes and interest will amount to nearly $1,500 and the total running expenses to about $10,000. On this basis the place should produce about $15,000.

If the place should comprise twenty or twenty-five acres, a much larger amount could be produced at a greater percentage of profit. Of course, more fertilizer and manure would be required, also an additional amount of pipe for irrigation, incurring an extra expense of $4,000 to $5,000, but the returns would be greater in proportion to the money spent than in the ten-acre piece.

The writer has endeavored to make the estimates large enough in every case to cover all necessary requirements. It depends on the man himself whether this place can be run at a profit. If properly managed and equipped as above, a market-garden of this size will net the owner as fair a return for the money invested as would be received in almost any other line of business.

As to crops, three should be grown in the houses and two in the field. By growing the staple crops, such as lettuce, cucumbers, radishes, rhubarb, tomatoes and parsley, in the houses, and cabbage, beets, peas, beans, tomatoes, spinach and celery in the field, with abundance of manure or fertilizer and plenty of water, there should be no failure of any crop, and a full crop always brings a full return.

The writer would recommend that no fruit or shade trees be on the place or around it. It will be much cheaper to buy fruit than to grow it unless there is a small orchard by itself, which is in good condition and does not interfere with the market-garden. It is also not necessary to have any hay land, as it will cost more to grow the hay than to buy it unless a large quantity can be grown, which of course would be impossible on a ten-acre farm. Then, it takes time to care for the hay, which always comes in the busy part of the vegetable season, when time is worth more expended taking care of the garden crops.

Fig. 222. Intensive market-gardening, New York city.—The hotbeds and coldframes occupy a considerable area. The small areas of the different crops are seen in the foreground.

Fig. 223. Cabbage grown by intensive methods.

The writer has had an experience of forty years in the market-garden business, having begun with 30 acres and at the present time cultivating 100 acres. The young market-gardener of today has great advantage over the one of forty years ago. There are at present many agricultural colleges to educate young men for this special line of work, whereas forty years ago there were none. These colleges and experiment stations are also doing valuable work for the more experienced market-gardeners, in showing them how to combat successfully the many insects and fungi which now destroy the crops. These are rapidly on the increase, especially in the greenhouses, and the protection of the crops from these pests has become a very important part of the business.

No matter how successful the market-gardener may be, there is always something for him to learn. Every place is different from others, some crops growing better on one man's land than on his neighbor's, and vice versa. By keeping account of the different crops, that is, the amount of yield and the return for the same, it can be easily ascertained which crops are the most profitable to grow on that particular place, and these crops should be adopted.

EQUIPMENT AND CAPITAL REQUIRED FOR THE CUT-FLOWER INDUSTRY

By *Anne Dorrance*

The following advice applies to roses only, and is based on the experience of one establishment consisting of thirty-seven greenhouses. These houses are built in two "ranges" (Fig. 224), one range being heated with steam, the other with hot water, each range having its own heating plant and cross-house. The individual houses vary in width from thirteen feet to twenty-three feet four inches, and are one hundred and fifty feet long. Cut-roses are the only product, each house being devoted to one variety of rose. Two small houses, ten by one hundred and fifty feet, are used for propagating and for housing the young plants.

In choosing a locality in which to establish a business for forcing plants for cut-flowers, three very important items are to be considered: first, economy in obtaining fuel; second, nearness to a good and sufficient market, or satisfactory express and railroad services to the market; third, suitable soil.

Glasshouses.

The successful forcing of roses depends very largely on an abundance of light: hence, the question of light and shade must be considered in choosing the site. The ranges described have their cross-houses, running due north and south, with the greenhouses proper running east and west. The idea is to so place the houses that the rays of light will fall as perpendicularly as possible on the glass. It has been suggested that a better method would be to deflect the whole range a little to the west, thus getting more sunlight during the short winter days. The houses should be sufficiently far apart that the ridge of one house may cast no shadow on the one immediately behind. The same consideration must be given to other buildings in the neighborhood, also to the proximity of factories or railroads using bituminous coal, as the smoke from this coal cuts off a large share of sunlight and makes a greasy, obscuring deposit on the glass.

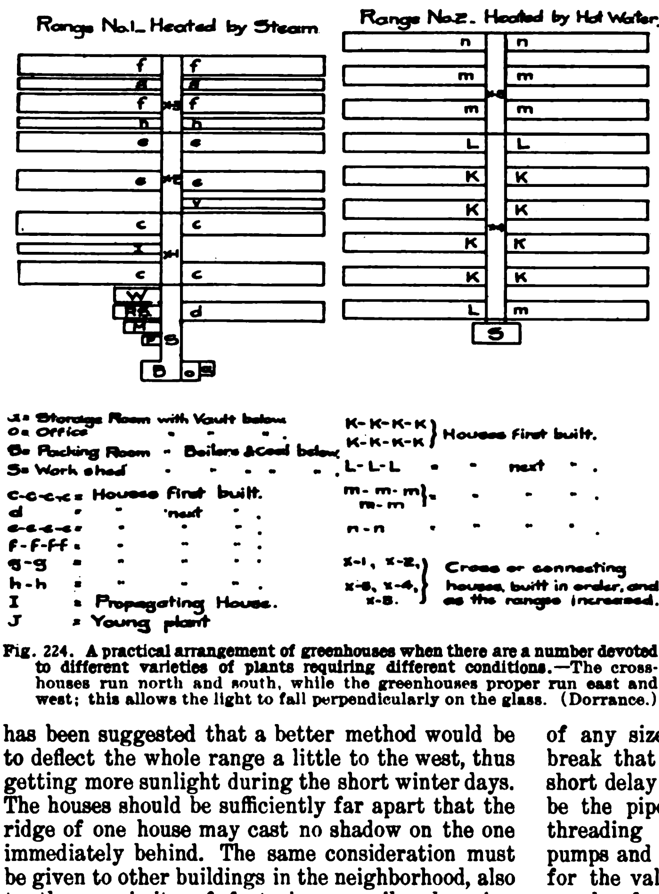


Fig. 224. A practical arrangement of greenhouses when there are a number devoted to different varieties of plants requiring different conditions.—The cross-houses run north and south, while the greenhouses proper run east and west; this allows the light to fall perpendicularly on the glass. (Dorrance.)

Aiming to eliminate all shadows possible, modern methods substitute iron whenever practicable for the heavier wooden construction. In this way, iron rafters, purlins, angle-irons and purlin posts are used. Second-hand pipe makes as good purlin posts as new pipe, and at a less cost. Red cedar posts have lasted well, and when coated with a mixture of oil and charcoal they are said to be practically imperishable. The sash-bars should be as light as is compatible with the size of the glass and weight of the roof. The glass should be large and free from bubbles or defects of any kind, as these form lenses, burning the foliage and disfiguring and lowering the value of the cut-roses. The ventilators are sashes sixteen feet by three feet, on the north side of the roof, hinged at the bottom. The benches are of various widths, dependent on the house in which they are built. Each house has its runs of small pipe, coming off the main flow from the boiler and going back into the main return. The flow and return run through a cross or connecting house of varying width.

The heating equipment consists of boilers with their main flows and returns, and the necessary buildings. The arrangement of these differs for hot water and for steam. The boilers described are horizontal tubular, having a grate surface six feet by eight feet, with the bars adapted to the burning of No. 1 buckwheat coal (anthracite). The draft is natural, but with a forced draft a smaller and cheaper coal could be used. The boilers are in a cellar, the water of condensation from the steam returning by gravity to the boilers; the same force governs the return water in the hot water range. The more modern way is to place the boilers at the level of the houses, returning the water mechanically.

Tools.

The tools needed will fall under three general heads. First come those of construction, if the proprietor be his own builder, the necessary carpenter's tools, a forge and tools for cutting iron and drilling it for the different bolts and screws used in construction. The second head is closely related to the first, and includes mainly the tools needed for repair. These should be on every place of any size, to repair quickly and thoroughly a break that might come on a bitter night, when a short delay would cost a year's labor. Such would be the pipe-working tools, wrenches, cutting and threading machines, rubber for packing valve pumps and unions, and some asbestos wick packing for the valve stems. To these must be added a supply of pipe of the various sizes, with fittings to match. All fittings should be malleable, with a bead. Lead and oil should be provided. The third head includes the tools belonging to the greenhouse work proper. Much of this work will require a team, although not for full time. Forks, spades, shovels and wheelbarrows for use at planting time must be supplied, spraying outfits, devices for fumigating tobacco in its different forms, nozzles to use in syringing, hose,—a most important and expensive item,—a watering can with a fine rose, twine and raffia for tying up, wire and wire stakes for tying to. Miscellaneous tools will be needed.

Water-supply.

The question of water-supply is very important. The houses must be so piped that water can be put on the benches when needed, and quickly. If the hose bibbs are put forty feet apart the work goes on very satisfactorily. The water must have sufficient force to be efficacious in syringing to dislodge the red spider. This problem has been solved by using a pump, drawing the water from a tank about 15 x 50 feet, and sending it over the range. The water is tempered by steam in cold weather. From a smaller tank built in two compartments, one for manure, the other for the liquid, manure water is pumped whenever needed in the houses.

Soils and fertilizers.

The houses built, heated and equipped, one more step must be taken before the plants can be put on the benches. This is getting the soil. The soil is laid up in a compost, alternating soil and manure, stacked in spring or autumn, and cut down at the proper time and put in the benches. Many growers now work the soil in the field and haul it directly to the house. Of additional foodstuffs, bone meal and wood ashes are essential; air-slaked lime is used on the soil in the benches before planting. Throughout the year feedings are given in the form of top-dressing and liquid manure. The benches are prepared for the soil by thorough cleansing and a good coat of lime wash to which has been added thirty pounds of sulfur for each bushel of lime.

Plants.

The young plants are a vital part of the business, for on them depends the success or the failure of the year; and, as this business is in a measure self-sustaining, all years are dependent on the first year's plants. It pays to buy the best, and, when propagating time comes, to select good wood and give the young stock most careful attention. The propagating bench or house must be proportionate to the size of the establishment. When this warrants it, a separate house should be set apart for the propagation. It can be under more complete control and be thoroughly disinfected if any fungous pest should get the upper hand. Roses are increased by cuttings, grafting and budding. Cuttings are used at the place here described. In about four months after the cuttings are put in the sand, the plants are ready for the bench and should be in a fine healthy condition, in 3½-inch pots; in about two months more they are ready to be cut from, although discretion should be used not to strain the young plants.

Employees.

The place under discussion, when fully manned, has its foreman, with two rangemen and a man for each three hundred running feet of house; or a boy may be put with an experienced man and the two given 600 feet of house. A number of boys are employed, being trained to take the vacancies as they occur. Each range has its night-watchman, who keeps the temperatures and does the night firing. During the cold months, a day fireman is employed. Men are kept who can repair breaks in pipes or glass. The grading of the cut blooms is done by a woman. At those seasons when extra help is needed, day laborers are hired. They gather, stack and cut down the soil, and put it in the houses. The regular force is divided into gangs who do the Sunday and holiday work.

Market.

More depends on the success of the marketing than on any other one part of the undertaking. The market may be local or distant. The care of the product up to the point of shipment is the same in either case. The roses are cut and brought into the grading room, where each rose is inspected and judged as to its perfection of bloom, foliage and stem, and put into its proper grade. The roses are put into pots of cold water and set in a cold vault to stiffen up, or "harden," as the term is. After they are brought into condition they are packed for the shipment. If the market is local, they are carefully laid in trays or paste-board boxes. If the market is distant, great care must be expended on the packing. Corrugated paper or wooden boxes are used. Those boxes known as "shooks" have proved satisfactory; coming from the mill "flat," they are made up into a box whose inside measurements are 5½ x 11½ x 48 inches. After the roses are taken out of the boxes, the boxes are knocked down, returned flat, and made up again for another trip. Expense of paper, wax,

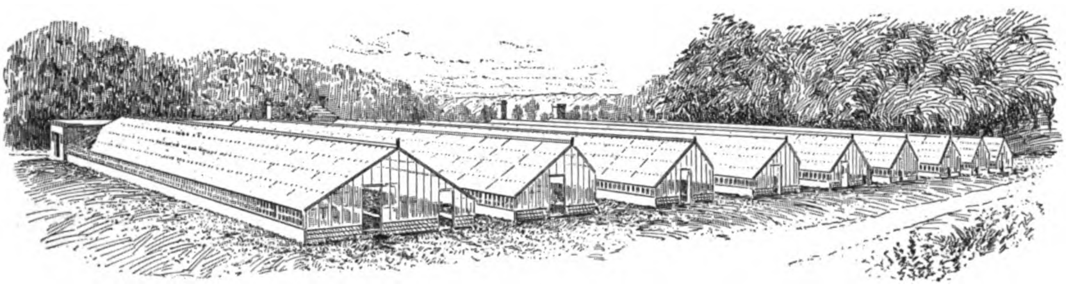


Fig. 225. Nesting of glasshouses in a commercial florist's establishment.

and manila, tissue and heavy wrapping paper, and sisal rope for tying boxes must be added.

Capital.

In order to start on a firm business basis, giving satisfactory progress and profit over the general running expenses, a range should consist of not less than six hundred running feet of greenhouse, twenty feet wide. Any increase over that amount should produce a proportionately greater profit. The capital required for such an establishment would depend on the following:

1. The permanency of the instalment.
2. The ability of the proprietor to plan and direct the erection of the heating plant and greenhouses.
3. The market price of the commodities used — glass, pipe, boilers, iron, lumber and so forth.

The following figures are based on market conditions in the autumn of 1905, and on first-class contract work, such as would be given by one of the many firms planning and equipping greenhouses, turning them over to their owners complete, with connections for the flows and return, ready for the soil. A safe estimate for the construction of a greenhouse 20 feet wide would be $15 to $18 per running foot. This sum would cover the entire erection of the house, piped for steam heat and water, with the ventilating apparatus. The instalment of the heating plant proper, including boilers, main flow from and return to the boilers, and the necessary buildings, would be additional. If boilers of just sufficient capacity to heat the 600 feet of house were placed, the cost would be not far from $2,000. If the range be built with a view to increase, the cost of installing boilers sufficient in capacity to heat 1,200 to 1,500 running feet of houses, would probably not exceed the above estimate by more than $500.

There should be an additional capital to run the place until it becomes self-supporting, or for one season. This would be expended in buying tools, getting the soil on the benches, buying plants and coal, the latter for a period of nine months, and paying the wages for the same length of time. In the Wyoming valley, Pennsylvania, such a range of glass would take 400 tons of anthracite coal per annum, of the size known as No. 1 buckwheat. The wages will depend on the number of men required, and, with the coal, will be governed by the market price. The number of men would depend on the experience of the owner. A practical man with a fair experience would need one young man as assistant and, during the cold months, a night fireman. If the proprietor is entirely inexperienced, it would be well worth while to employ the most skilful labor possible until he is competent to take charge of the place.

To recapitulate:

600 feet of house, at $18 per foot . .	$10,800
Heating plant for same, complete . . .	2,000
Additional boiler capacity, allowing for increase	500
Capital for running expenses, first season.	2,000
	$15,300

The return on this will depend on the quality and quantity of the product and the market, but a fair profit would be 10 per cent on the capital invested.

CHAPTER VI

FARM MACHINERY, IN RELATION TO EQUIPMENT

MACHINES ARE AGENTS FOR ECONOMIZING HUMAN LABOR AND IMPROVING ON IT. They multiply a man's capabilities, and give him dominion. In many cases they also enable the farmer to produce a better crop or a finer market product. The American farmer is known by his machines and implements, a condition resulting in part from cheap land and dear labor. These devices constitute such an important and distinct part of the equipment of a farm that they may be considered separately from other equipment. The machines and contrivances that are peculiar to certain industries will be treated when those industries are discussed.

With all the development of special farm machinery, there is still much lack of adaptation in it, resulting from the fact that invention of machinery is so often divorced from good farm practice. Farmers are likely not to know the principles of mechanics, and manufacturers not to know farming. No doubt some of the machines are an expression of the inventor's ingenuity rather than a frank effort to meet actual farm conditions for the benefit of the farmer. The enormous multiplication of labor-saving appliances adds greatly to the complexity of farming. The agricultural colleges and experiment stations will soon need to make and publish tests of the values of various kinds of machines and tools, much as they now do of fertilizers, not alone for the immediate good of the farmer, but also to guide the further invention of machinery. The colleges are beginning to establish departments devoted to farm mechanics and machinery; for the complexity of the mechanical problems calls for knowledge of principles and skill in practice.

Although farm machinery has attained great development in North America, the discussion of it has not yet concreted itself into printed treatises. In 1859 John J. Thomas wrote a book, published in New York, called "Farm Implements." In 1869 this was republished as "Farm Implements and Machinery." Another historic work is John Stanton Gould's "Utica Plow Trial," published at Albany, New York, 1867. The subject is treated in some of its phases in chapters in many books, and in experiment station literature. Following are some of the useful special publications in English: Chapters on "Farm Mechanics" in F. H. King, Textbook of the Physics of Agriculture (second edition, 1901); R. L. Ardrey, American Agricultural Implements, Chicago, 1894; George A. Martin, Farm Appliances, New York, 1892; Farm Conveniences, A Practical Handbook for the Farm, New York, Orange Judd Co., 1893; Eldredge M. Fowler, Agricultural Machinery and Implements, in Chauncey M. Depew's One Hundred Years of American Commerce, Vol. 2, pp. 352–356; Edward Stabler, Overlooked Pages of Reaper History, Chicago, 1897, W. B. Conkey Co.; Census Bulletin No. 200; Thirteenth Report of the Bureau of Commerce and Labor; United States Department of Agriculture, Division of Statistics, Miscellaneous Series, Bulletin No. 18, Course of Prices of Farm Implements and Machinery for a Series of Years, by G. K. Holmes; J. Wrightson, British Agricultural Machinery, London, 1876; Robert Scott Burn, Textbook of Farm Engineering, London, 1878–84; James W. Hill, Compiler, Illustrated Guide to Modern Agricultural Implements, Tools, Machinery, etc., London, 1880; John Scott, Complete Textbook of Farm Engineering, London, 1885; William Burness, J. G. Morton and Gilbert Murray, Equipment, second edition, London (Morton's Handbook of the Farm No. 6); Tillage and Implements, London, 1891; W. J. Malden, Farm Buildings and Economical Agricultural Appliances, London, 1896.

THE UTILITY OF FARM MACHINERY

By *John W. Gilmore*

The greatest factor in the value of machinery is its adaptation to purpose, and the greatest factor in its period of usefulness is the care that is taken of it. Farmers have many things to do—the soil, the plant, the animal, the market and the community all demand their attention. So far as the first three activities are concerned, farmers occupy both the position of directorship and executor. With all these activities and the limited resources which the farmer has, it is not strange that he may not be able to work a machine in accordance with its greatest efficiency. Hitherto the manufacturer has followed the strict principles of mechanics and machine-shop methods in the machines which he has made. The teaching of farm machinery and rural engineering in the colleges has for one of its objects the closer association of the knowledge of mechanics for the farmer on the one hand, and that of farming for the implement manufacturer on the other.

Although the manufacture and use of farm machinery has grown very rapidly and extensively in recent years, it is not probable that hand labor will be entirely supplanted in the successful production and handling of crops. Some of the best and most far-reaching plans for the management of the farm are laid while the hands are busily engaged in work to which they are naturally accustomed; therefore it will not be out of place to consider the subject of the utility of farm machinery as associated with some hand labor.

The utility of the hand implement.

There is much philosophy in the construction of the hoe. Every farm reader remembers as a boy farmer of being tired at night from manipulating a hoe constructed of heavy metal with a big, clumsy handle. The present hoe is light, elastic and much better suited to accomplish work with a calm temperament than was the old, heavy implement of past years. The old hoe, however, was not altogether out of place. In those days tillage implements were not so perfect as they are now, neither were they so extensively used. In many instances entire crops were produced without the use of tillage implements as we now understand them, therefore the old hoe was not only a weed-killer and a backbreaker but was also a cultivator.

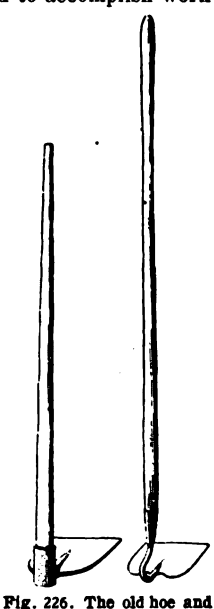


Fig. 226. The old hoe and the new, showing the improvement in form.

The pitchfork, too, embodies some principles of construction that those who do not handle it perhaps may not appreciate. Every farmer has his own fork, and his choice is not based so much on the looks of the implement as it is on the facility which it renders in handling the hay. The delicate curve in the handle formed only in one plane and the nice balance of the tines are points of construction which can readily be judged by one experienced in the handling of these tools. An experienced wood-chopper knows a good axe by its "feel" or "hang." This conception of utility is not a trivial matter to a person who uses these implements for an entire day.

The plow and harrow.

Man and the plow have developed side by side; and the writer sometimes wonders whether the plow has not had as much influence on the development of man and the direction of his lines of advancement as any other object with which he has been associated so long. It is true that he has frequently turned aside to improve this implement and adapt it to his immediate needs and conditions, but it is remarkable that an implement so simple in its principles of construction has received so few touches of improvement when compared with more complex machines which are infants in age by its side. It is only in recent years that the greatest improvement has been made. Now it is an implement of much beauty, as well as of utility when used understandingly. The first plows merely scratched the land. The next great improvement was to turn the land that it might be exposed to the weather. Not until near the middle of the past century was it conceived that plowing might be improved by shaping the moldboard in such a way as to cause motion between the soil particles when turning a furrow-slice. This great benefit is accomplished by constructing a short bold moldboard with wing projecting. The work done by the moldboard consumes only about 2 per cent of the draft of the plow. It is not economical, therefore, to sacrifice this principle of tillage for plows of a straighter

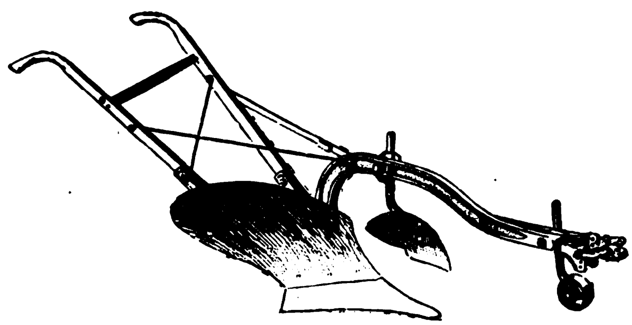


Fig. 227. The light, strong, effective plow, the product of centuries of experience.

moldboard which merely turn the furrow-slice flat. The larger part of the cultivated areas are now in such condition that there is little further use for the long, twisted moldboards that were first used in subduing the prairies.

The draft of plows under ordinary field conditions ranges from 400 to 500 pounds. Sometimes in preparing oat stubble for wheat it will run as high as 600 pounds. The conditions of soil, both as to texture and moisture content, affect the draft materially, but under general conditions it may be divided as follows: Twelve per cent of the draft is due to the work of turning and pulverizing the furrow-slice; about 33 per cent is due to the friction of the pole on the sole and landside; and 55 per cent is consumed by cutting and lifting the furrow-slice. Much effort has been expended in reducing the friction of the plow without reducing the efficiency of the work done, both in depth and width of cut as well as in pulverizing effect produced by the moldboard. In all probability the improvement along the line of draft in the future will be made by employing better and more efficient draft power. Stronger draft-horses are being bred, and the use of steam for plowing when the areas are large and sufficiently level is an economic development. The sulky plow embodies a feature that reduces the draft somewhat in proportion to the amount and kind of work done. The presence of wheels, and especially of the third wheel, which works in the furrow, makes it possible to reduce the length and width of the landside without reducing the ease of working the plow. This, in fact, is one of the important features in the adaptability of the sulky plow.

The jointer, or skim-plow, as an attachment, is one of the most important improvements that has been made on the plow. Its intelligent use renders a much broader utility of the plow than would be possible without it. Tenacious sod can be worked satisfactorily if the jointer is set deep enough to break the rigidity of that part of the furrow-slice that remains uppermost. On the other hand, stubble and cultivated lands are rendered more friable by its judicious use. When properly adjusted, it lessens draft and prevents the furrow-slice from being turned over too flat. Thus, soil warms up more rapidly in the spring, has a greater moisture-holding capacity, and is left in such condition that subsequent tillage by harrow or drag is facilitated. The jointer also aids materially in turning under manure or rubbish that may be on the surface of the soil.

The disc-coulter, while serviceable in clean sod lands, is not adapted to lands covered with stones or any material that cannot readily be cut. In tenacious sods the disc-coulter lessens the draft somewhat by cutting away the furrow-slice from the land, thus reducing the amount of work required in lifting and turning the furrow-slice.

Other features of the adaptation of the plow are found in the length and set of the handles. This effect is manifested more by the ease of handling the plow than on the work which it does. In the best plows the handles are about the same length as the beam and are set with the left handle slightly over the land. With this proportion and set, the handles will be at an angle of about 30° to the direction of the beam. A very slight variance from what is correct in this position will be readily detected by the plowman after a day's work. The straight line drawn from the hames of the harness and passing through the point of attachment at the bridle of the beam, should pass also through the center of draft of the plow, which is located behind the mold-board and about 2½ to 3 inches from the side and bottom of the furrow. If this straight line is deflected downwards at the bridle of the plow, perhaps a slightly better effect is produced, as this does not make it necessary to use a pitch point on the plow. The pitch point increases the draft out of proportion to the work done and is solely for the purpose of holding the plow in a tenacious, stony soil or in correcting poor application of draft. The line of hitch or pull should also be about in line with the direction of the landside; that is, a plow cutting more or less than its standard width does so at a disadvantage because undue friction is brought on the landside.

If only two tillage implements were to be used on farms in general, the greatest advantage would be derived from the use of the plow and the spring-tooth harrow — the plow to prepare the land and the harrow to fit it for the crops. With the present method of adjustment to depth of the various harrows, they are adapted to a very wide range of conditions. On soils in general, for the amount of soil stirred and the depth to which it is stirred as compared with the draft, the disc-harrow is the most economical. This adaptation of disc-harrow renders it possible to supplant the plow under some conditions of loose soil and shallow preparation. The disc-harrow, does not fine or pulverize the soil satisfactorily nor produce the sub-surface packing that is requisite to the best growth and development of some crops. The smoothing harrow, on the other hand, only fits the surface of the soil, and it requires greater draft in proportion to the amount of soil stirred and the depth than any other harrow.

The spring-tooth harrow is adapted to a wide range of conditions and uses. It may be used entirely for tearing up the surface of plowed land, and also under different adjustments for fining and smoothing the surface. Some harrows are fitted with a smoothing attachment in the rear, and by this attachment admirably serve the purpose of smoothing. For cultivating corn and potatoes before they are up it is very useful, and it can be used, when the land has been properly prepared, for covering small seeds, such as the larger grasses, clover and alfalfa.

The use of the harrow is almost inseparable from that of the plow. The plow, when judiciously adjusted and used, not only breaks up the compact mass of soil but it also compresses the soil to a certain extent by its wedge action. The harrow is the necessary implement for breaking up these compressed masses of soil, and it is useful for this purpose in both sod and stubble lands. [Further discussion of tillage tools will be found in Part II.]

Hay-making machines.

The mower, while primarily a hay-making machine, is also used extensively in some parts of the country for cutting weeds. When used for such purpose, it often has some rough service and must have rigid construction. The mower must drive its cutter-bar more rapidly than the reaper, because the stems of grasses, clover and alfalfa stand more thickly than the cereals, and besides they must be severed by a shearing cut, while the stems of the cereals may be partially snapped. The mower makes about 22.4 strokes per yard

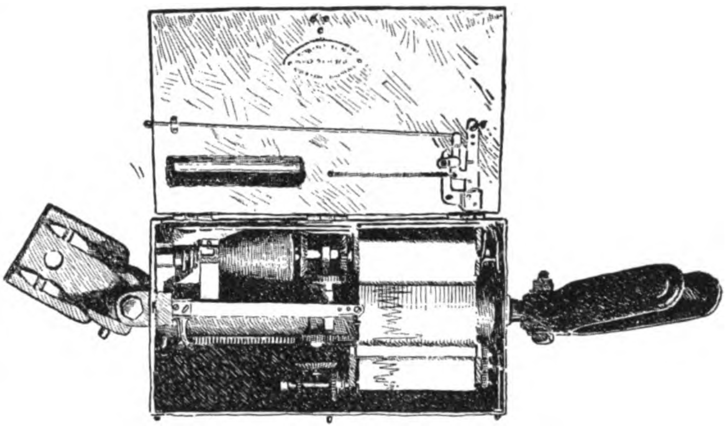


Fig. 228. Instrument for measuring the draft of farm machinery.

of ground passed over, while the reaper makes only about 7.5 strokes for the same distance. The knives on the mower knife-bar are usually smooth and must be kept sharp, otherwise the draft is greatly increased, and the material to be cut may be pushed over and not cut smoothly.

The best machines are now constructed so that while the cutter-bar is elastic, yet it does not easily wear and get out of alignment with the pitman. Most machines have adjustments for this difficulty. Much of the draft of a mower is consumed by the thrust of the pitman against the cutter-bar. The attempt should be to make the angle of elevation between the cutter-bar and the pitman as small as possible. The draft on a 5-foot mower averages about 340 pounds, but this may be increased to 550 or more pounds by dull knives or by gearings and bearings that bind. Some advantage is asserted for the chain-gear because it eliminates some of the friction occasioned by cogs in transmitting the power to the same point. A 6-foot mower pulls more heavily than a 5-foot machine, but the extra draft is not excessive in proportion to the increase in cut and in time saved. A 6-foot machine, however, is more subject to wear and tear due to irregularities of the field, since it must have a wider wheel tread in order to balance the pull.

The tedder is one of the most important of hay-making machines. The quality of the hay and the facility of hay-making in the eastern or humid states have been greatly increased during recent years by its use, and it is now playing a most important part in the making of alfalfa hay in those sections of the country where it is difficult to get a sufficient period of dry weather for curing this crop. It renders valuable service also in the making of mixed clover and timothy hay. The mower usually leaves the stems of grass or clover in a more or less regular position, and on wilting they settle down close to the moist earth. The tedder is the implement needed to raise the material from the damp ground in order that its curing may be hastened. Both the aroma and the color are much improved, if the hay can be dried quickly to a sufficient degree to permit its being stacked into cocks. In the humid regions it has been found necessary to follow the mower almost immediately with the tedder, in order that the alfalfa and clover hays may be shaken up and exposed to air, otherwise they become bleached and unequally cured. The tedder should be wide enough to cover about two swaths of the mower, and it should be so balanced that the rapid motion of the forks will not vibrate the machine. It has the disadvantage, however, of picking up small stones with the hay, but this need not occasion serious difficulty if the material is not brought in contact with silage cutters, shredders or threshers.

Grain-working machines.

The grain binder has rendered very great service in the increase of grain production in this country, but it has not entirely supplanted nor will it be able to supplant the use of the cradle and the reaper in some sections. The conditions under which the cradle is largely used at present and will continue to be used are in the mountains and uneven parts of the country, where fields are small and considerable difficulty is occasioned in moving the binder over the field and from place to place.

The reaper still finds a very extensive use when oats are grown in rotation. Under such circumstances it is frequently desired to utilize the oat straw for roughage for cattle and horses and even sheep, during the winter, as it possesses considerable nutrients. The reaper serves this object by enabling the farmer to cut his oats and cure them earlier than could be done if they were bound directly into sheaves on cutting. The oat straw is not so thoroughly dry and withered at the time the grain is ripe as is the case with wheat and some other cereals.

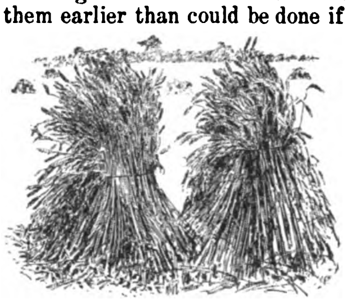


Fig. 229. To show two ways of tying sheaves. The one at the left is the better.

In operating a binder, some important points may be noted. The best binders are provided with a very convenient and easily operated mechanism for shifting the position of the band on the sheaf. This is demanded because the grain is of unequal height in different parts of the field, and different forms of bundles may be wanted. A sheaf of wheat bound a little beyond the middle of the straw is more easily handled, both on the wagons and in threshing, than is one bound too near the top, as is frequently done (Fig. 229). Much of the grain which might otherwise be lost is thus saved. When timothy or other grasses have been seeded in the grain it sometimes happens that these have attained a considerable growth before the wheat is cut, and in such cases the band should be placed near the top of the sheaf in order that this grass may either drop out or be readily cured.

The reel of a binder is often worked high when it should be worked rather low. If it is placed too high the standing grain is thrown on the apron at the time too quickly, so that it lies slanting between the elevator canvasses and, therefore, cannot be packed into a neat bundle on the binder table. If the reel is worked low, the entire plant may be passed on the apron at about the same time after it has been cut, and thus facilitate in keeping the binder clear as well as in making a neat bundle. When binders have to handle various grains, including rye, some provision is usually made for the extra length which may be attained by the rye, by removing the rear board of the cutting platform, as well as that of the binder platform. The draft of the binder is usually in the neighborhood of 600 pounds, but, like the mower, this depends very largely on the sharpness of the knives, as well as on the presence of green material to be cut. This large draft usually requires the work of three horses. Some recent machines have been made on roller bearings, and this lightens the draft considerably, although increasing somewhat the cost of the machine. The draft is also largely influenced by the topography of the field, and this also has much to do with the period of its usefulness, as rough roads and rough fields occasion much wear on the large machines.

The subject of threshers is discussed in the following article, but something should be said in favor of the small stationary thresher for individual farm work. The traction engine has done much to overcome the difficulty of rough roads and of moving large machines from place to place, but there still remain conditions where the small thresher is of use to the individual farmer; and it soon pays for itself when other branches of farm work demand the presence of an engine, and also when two cereals—wheat and oats—are utilized in the rotation employed. On even moderate-sized enterprises there is usually enough of such work for a thresher to occupy parts of rainy days and other occasions when straw is required for bedding. It is evident that on general-purpose farms, when every diligence is exercised in the preservation of manure, these threshers have a very important place in making possible a more economical use of straw and of material which is used for bedding and finds its place in the farm manure.

These threshers are usually small enough to occupy some convenient part of the barn, having a cylinder about two feet long and capable of being operated by engines of 8 to 12 horse-power. It is true their capacity is small, but their operation does not usually require other than the regular force employed. Both the blower and elevator methods may be conveniently employed for storing away the straw in the mow.

Drills and planters.

One important factor in the utility of an implement is the number of purposes to which it is adapted. Often it is not well to try to make one machine serve too many purposes, but the grain-drill may be an exception to this. The climatic conditions throughout the United States where small grains are produced vary greatly; consequently, a number of types of drills have been made adapted to these different conditions. In the drier sections of the Middle West, where there is not an abundance of moisture after planting in the spring, a small wheel is attached to the rear of the spout which serves the purposes of pressing the soil over the seed and thus hastening germination. This arrangement prevents the necessity of planting deeper than normal conditions require. The small garden-drills are also provided with this convenience, which renders good service in planting garden seeds of varying sizes and it is adapted to varying conditions of soils and moisture. In many parts of New England and the Middle Atlantic states, where the soils are heavy and have a tendency to bake, this press-wheel on drills is not considered desirable. In fact, it is a detriment because the sprouting crop is better provided for when the surface of the soil is left rough.

The disc-drill is also used very extensively in many sections of the country where the soil is loose, friable, and possesses a high content of organic matter. Under such circumstances it is not infrequent to plant small grain without replowing the land. The disc serves the purpose of breaking up the surface of the soil in the row and leaves it in a sufficiently loose condition for proper germination of seed. The shoe- and hoe-drills are largely used in the eastern part of the country, where the soil is thoroughly plowed and fitted for the crop before seeding. While drills vary considerably in their dimensions, especially in the total width of ground covered and the distance between spouts, there is a very extensive use of the 7 x 11 drill, that is, a drill having eleven spouts, the spouts being 7 inches apart. These dimensions are adaptable to a wide range of purposes. Not only is the drill of this size suitable for the planting of cereals because its weight is adaptable to the average condition of draft in the hillier parts of the country, but it is also adapted to sowing other crops than small grains. The grain-runs are usually of two sizes, a small and a large. By using proper runs and stopping up some of the spouts, beans and other large seeds can be sown. For beans, corn and mangels, the seeds are usually sown through the large run, and three spouts are stopped for beans, allowing the first and fourth to plant; four spouts are stopped for corn and mangels, allowing the first and fifth to plant.

These machines are also adapted to planting seeds at different depths by throwing the hoes forward or backward, as may be desired. Another feature of grain-drills is their adaptability for sowing both fertilizers and lime. Those machines having a force feed serve this purpose most admirably. In recent years, lime suitable for agricultural purposes has been put on the market in a pulverized form. The pulverizing is performed by machinery. When such lime is handled in barrels, it reduces very largely the disagreeableness of slaking and handling it in the ordinary way. Usually lime should be applied at the rate of one to three tons per acre. Most of the grain-drills are not adapted to applying such large amounts at one application, but, in all probability, as much benefit may be derived in the end by applying lime in small amounts annually. Of course, there are lime-spreaders on the market which work successfully, but the small amounts of lime used and the infrequency of application may not justify the purchase of a separate machine for this purpose. All drills sowing fertilizers should be carefully and thoroughly cleaned after service. Many fertilizers, especially those containing chemicals, have a corroding effect on metals.

There are many conditions in the United States in which hand planters for corn are very serviceable. Farms on which the producing power is kept up to a high degree, are usually those that keep live-stock, and also those on which some systematic and judicious rotation of crops is practiced. On such farms of average size it may not be desirable to plant more than ten or fifteen acres of corn, and this is mostly used for silage. The ground is often hilly, and corn-planting may come at that season of the year when labor can be spared for the purpose. On the hilly and newly-plowed lands the corn can be more perfectly check-rowed by hand-planting than it can with the machine, and this adds much in the convenience of keeping the crop clean. On level lands and on large areas, the machine planters are very adaptable, especially those with the wire trip, which enables one man and team to plant two rows at a time. It has been found that under general conditions more dry matter from corn can be produced by planting the corn in hills than can be produced by planting in drills. It is true, however, that corn planted either broadcast or in drills may be made into dry forage more readily than when planted otherwise, but this convenience is secured at the expense of total yield of dry matter; therefore, the principal requisite in corn-planters is regular, uniform planting without missing hills, and in such a way that the field may be cultivated in both directions.

The potato-planters now on the market are capable of much improvement. There is economy in their use when more than four acres are to be planted. As a general rule, however, they do not plant deeply enough, neither are the sets which they handle sufficiently large to insure a maximum crop. One objection to the deeper planting with the machines is the large draft required. The draft of a machine planting 3 to 4 inches is in the neighborhood of 450 pounds, while to plant 6 inches deep requires generally about 600 pounds. This is beyond the strength of average teams. It is not improbable, however, that much improvement will be made along these lines.

MACHINERY IN RELATION TO FARMING

By *C. J. Zintheo*

Very few persons realize the importance of the development of modern farm machinery and its effect on the development of North America. The success of agricultural pursuits depends primarily on the accomplishment of the largest possible results at a minimum cost. The American farmers are the largest users of farm machinery, and it is largely because of this that the continent has become the greatest agricultural country.

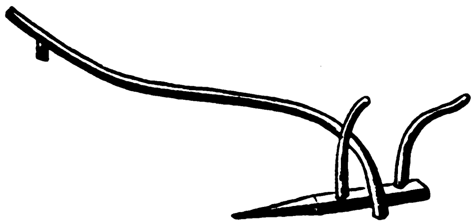


Fig. 230. "Aratrum Nativum, an Original Plough," "used by the ancient Husbandmen." From Bradley, "Survey of the Ancient Husbandry and Gardening," 1725.

In the first two hundred years after the Pilgrims settled on the American shore, the abundant natural resources of the country failed to bring any great increase in the products of agriculture. As late as 1845 the people of the United States did not raise enough wheat for their bread. With the advent of the steel plow, the self-binding harvester and the steam threshing-machine there was a marked change in the producing power of the American people. The food supply increased from 4.33 bushels of wheat per person in 1845, to 5.5 bushels in 1859, to 7.45 bushels in 1869, and became as high as 10 bushels in 1889. In the same epoch, the population on the farms had decreased to 80 per cent of its proportion in 1850, and to 33 per cent in 1900. The farmers of today, employing less than one-third the labor of the country, produce enough food to support not only themselves, but the other 67 per cent of population, and they exported farm products in the year 1904 to the value of $960,000,000. Much of this achievement is, no doubt, attributable to the fertile soil of the great plains and valleys; much to the progressive spirit and intelligence of the farmers of America; but more is due to the persons who have developed the modern farm implements and machines and have supplied the farmers with tools, thereby enabling them to sell their products of the agricultural staples in the open market of the world in competition with the poorly paid laborers of Russia and India.

Implements and machines will be still more important in the future, because it is mainly through them that the farmer can reduce the cost of production. To illustrate this, it is only necessary to state that in 1830 it required over three hours' labor to raise one bushel of wheat, while in 1896 it required ten minutes, making a saving in the cost of labor in one bushel of wheat equal to the difference between 17¾ cents and 3½ cents. In 1850 the labor represented in a bushel of corn was 4½ hours, while in 1894 it had been reduced to 41 minutes. In 1860 the labor in one ton of hay in bales represented 35½ hours, while in 1894 this labor was reduced to 11½ hours, or from a cost of $3 in labor to $1.29. The agricultural implements in the United States saved in human labor in 1899 the vast sum of $681,471,827. American farmers buy annually $100,000,000 worth of implements, and the total value of the implements and machinery on the farms in this country is $761,261,550. In no other country is such extensive use made of farm machinery; and the scarcity of farm laborers will tend to increase its use rather than otherwise.

Until about the middle of the past century, farm work was performed mostly by hand, the plow and the harrow being practically the only implements drawn by horses. Wheat was sown broadcast by hand, as in Bible days, and covered with the harrow, and corn was dropped in furrows by hand and covered by means of a hoe. Reaping was still done in most cases with the sickle and the cradle, which had remained essentially in their undeveloped form since the early history of the cultivation of cereals. The corn crop was picked and husked by hand, and the stalks, which constitute about 40 per cent of the value of the crop, were practically waste. Hay was mown with the scythe and collected with a hand rake. A wooden stick often served as a fork for stacking the hay.

Wheat must be harvested within a few days after it ripens, or it will go down and scatter, and the farmer's seed and labor and use of land for a year be lost; hence, the wheat crop, under the régime of the sickle and cradle, was limited to the few acres that each farmer could reap by hand. There was no demand for threshing-machines, as the farmer could store his small crop in his barn in the sheaf and flail or tramp it out on his barn floor at his leisure in the winter, and clean the grain by throwing it against the wind. There was no economy in grain drills, as a man could sow broadcast

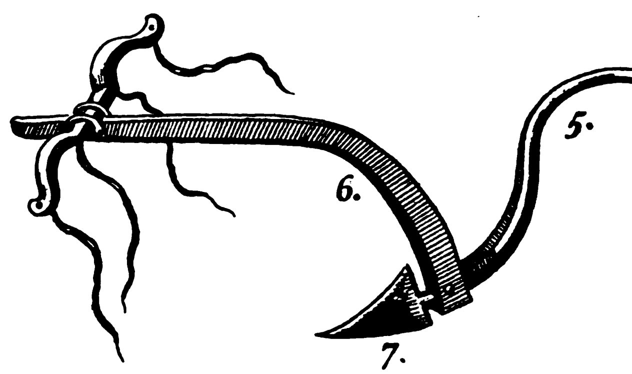


Fig. 231. "Aratrum compactum, an improved Plough. 5, Stiva, the Plough Tail; 6, Temo, the Plough Perch; 7, Dentate, the Plough Share." From Bradley.

by hand in a day as much as he could reap by hand in the entire harvest season.

The introduction of the reaper marked the beginning of a revolution on the farm. With a machine to harvest the grain rapidly and to increase thereby the acreage which each farmer could grow, there was economy in the use of other machinery, and a demand was thus created for modern farm tools. This was followed by a remarkable change in

Fig. 232. Plow still used in Chile.

commerce, transportation, manufacturing and the development of the great natural resources of the country.

Railroad construction took on new life; and the labor released from the farm and supplied by immigration doubled the output of factories from 1850 to 1860, and in 40 years multiplied the production of manufactured goods ninefold in value and perhaps twentyfold in volume, while population increased less than threefold.

The migration from the farm to the city caused no farms to be abandoned that can be cultivated by machines. The size of the farms has increased from an average of less than 50 acres to 137 acres. Some of this increase in size of farms may be due to land-hunger following the opening of the West, and to other causes; but much of it is also contingent on farm machinery. In the countries of the Old World the increase of population has decreased the size of the holdings, the average size farms being from five to twenty acres.

The significance of certain implements and machines.

The most important of all farm implements, and perhaps the most important implement drawn by animals or steam known to mankind, is the plow. Its gradual evolution is coincident with the history of the race. The crooked stick, the plow of centuries, merely tickled the ground. Inventors improved it by adding a sheet-iron plowshare and moldboard. Afterward came the cast-iron plow, which was followed by the chilled plow, the soft-center steel moldboard and the all-steel plow. The walking-plow was followed by the sulky riding-plow, the gang-plow and the disc-plow. Some stages in the evolution of the plow are shown in Figs. 230–245. With a gang-plow and five horses a man can plow from five to seven acres per day, completely turning over the soil, whatsoever its nature, and thoroughly pulverizing it. Plows are now being introduced with 10 to 20 14-inch plows in a gang, which are propelled by a steam traction engine and with which two men can plow from 40 to 60 acres per day. A 110-horse-power machine plows, sows and harrows at the same time a strip 30 feet wide, at the rate of three or four miles an hour, turning over the soil at the rate of 80 to 100 acres a day, or under favorable conditions 10 to 12 acres an hour. It thus performs work which ordinarily requires 40 or 50 teams and men.

Harrows of many kinds, such as peg-tooth, spring-tooth, disc, spader and pulverizer-harrows from 4 to 20 feet wide, follow the plow and prepare a seed-bed for the grain. There is a harrowing machine that reaches 100 feet in width, capable of harrowing 300 acres a day or 30 acres an hour. A whole section of land is harrowed in a little more than two days. No one has to walk in the loose soil behind the harrow, whipping up a tired team. Even the small two-horse harrows are often equipped with trucks on which the farmer can ride.

The man formerly had to sow his small grain by hand; this practice has been replaced by the use of the broadcast seeder and the drill. The latter is constructed in numerous ways, such as hoe-drills, shoe-drills, single-disc- and double-disc-drills. They are made in sizes up to 30 feet in width, and with one of them a man and team can plant from 25 to 30 acres per day. By means of specially constructed implements for planting and for cultivation to conserve the moisture in the soil in the semi-arid regions, where the rainfall amounts to only 10 to 15 inches per year, farmers are now able to raise crops of 30 bushels of wheat per acre, where formerly it required from 10 to 15 acres of the same land used for grazing to furnish nourishment for a single steer. One-third of the area of land in the United States which is capable of cultivation is in the semi-arid region. Parts of this may be made fertile by irrigation, but the larger part will have to be reclaimed by modern implements and subsurface packers; and the land will have to be tilled by cheaper forms of motive power than horses.

In the corn-belt, the man with the hoe who used to plant the corn has been replaced by the horse corn-planter. This plants two rows of corn at the same time in squares, the hills of which are a certain distance apart; and a certain predetermined number of kernels are dropped in each hill. By recent experiments, it has been found that by grading the corn kernels into uniform sizes by means of machinery, the uniformity of planting may be greatly improved and the yield of corn per acre be increased perhaps 20 per cent. The cultivation of the corn crop is now performed by a one- or two-row horse-cultivator, on which the man rides in a hammock seat. While formerly the practice of deep cultivation was considered advisable, recent experiments with various kinds of corn cultivators indicate that the best yield of corn is obtained when the tillage is shallow in the last cultivations. The reason for this is that the roots of the corn penetrate all the space between the rows, and deep cultivation injures or cuts off the roots, thereby reducing the yield.

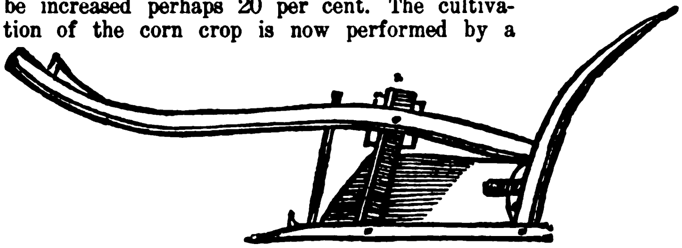


Fig. 233. "The most common Plough," of Mortimer's time. (Mortimer, "The Whole Art of Husbandry," London, second edition, 1708.) It was "called the Dray-plough, which is the best Plough in Winter for miry Clays, when the Land is soft; but the worst in Summer, when the Land is hard: Because the Point is always flying out of the Ground. This Plough is set higher or lower, as they find occasion, by Wedges at a."

The 50,000,000 acres of grass in the United States are now largely cut with mowers that cover swaths of 4½ to 8 feet in width. The grass-fields, after being mown, are gone over with the horse-rake, and the windrows left by the rakes are, on the smaller farms, gathered by hand. On the larger farms, the hay-loader is employed, elevating the hay on a wagon by means of endless belts or raker-bars. A late form of side-delivery rake "dry cures" the hay by picking it up out of the stubble and wafting it in the air. It is turned over and gently deposited on the heated ground in windrows, from which it is taken up by the hay-loader into the wagon. By this method, hay may be cured and stacked the day it is cut, thus retaining the greater part of its nutriment and color. In the West, where the hay is to be stacked in the field, the so-called "bull rake," a rake with long teeth, is used. It is drawn down the row by a horse hitched to each end until it accumulates a load, which is slid along the ground to the stack, and, by means of an automatic stacker, is raised and dumped on the stack. By these modern hay tools,—the mower, side delivery rake, hay-loader and the hay-fork at the barn to which were hitched three horses,—one farmer put 120 tons of hay in the mow between one and six o'clock.

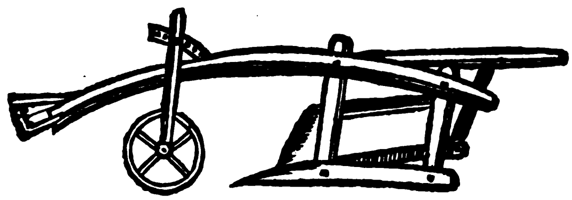


Fig. 234. Plough used in Sussex, "the single Wheel-Plough, which is a Sort of Plough I should not have mentioned, but for their different Make from most other Ploughs, because they are a very clouterly Sort; and as they are very wide in the Breech, I cannot but think the Draught of them to be very hard." (Mortimer).

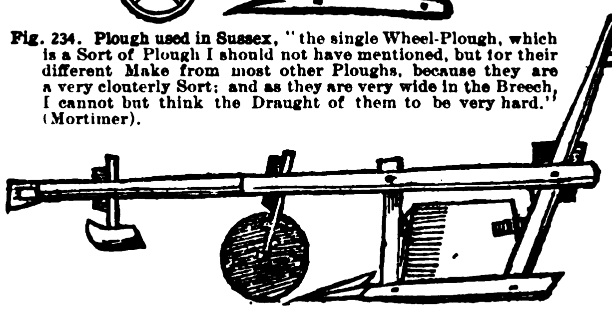


Fig. 235. The Lincolnshire Plough, "very particular in its shape, and is a very good Plough for Marsh or Fenny-Lands subject to Weeds and Sedge, and that is free from Stones." (Mortimer.)

The hand-sickle used for centuries to harvest small grain was early considered to be laborious and inefficient. At the beginning of the Christian era, Pliny speaks of the use of a machine consisting of a box mounted on a two-wheeled cart. On the front of the box was a series of closely arranged teeth, between which the stalk of the grain slid, and which were too close to allow the heads to draw through. An attendant walked beside the cart with a stick and beat the heads back into the box. A few modifications of this early cart were made, but it was not until the middle of the last century that any extensive progress was achieved. The self-rake reaper was then developed into its present form, but this machine has been practically displaced in this country, first by the harvester, which cut the grain and elevated it to a table, where two men bound it into bundles. Then the men were replaced by an automatic binder. First a wire binder was used, but, as the wire was objectionable, inventors soon found a way to use cord. With the automatic twine binder the straw is packed into bundles, wisp by wisp, against a trigger set at a predetermined stress, so that the binding mechanism is thrown into gear when the bundle is the proper size, and the bundle is bound and discharged. The next advance was the invention of a bundle-carrier, by which the bundles are carried into windrows, from which they are set up by hand into shocks of about 12 bundles each.

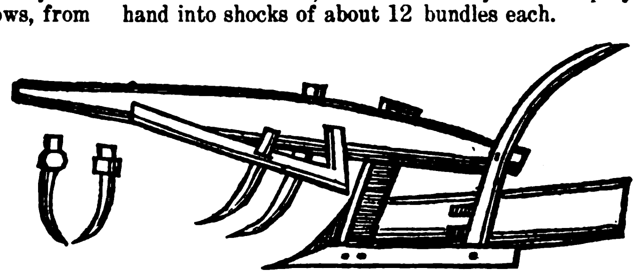


Fig. 236. Plough used about Caxton in Cambridgshire, for draining wet lands. (Mortimer.)

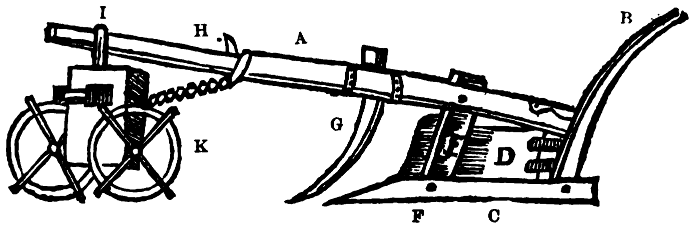


Fig. 237. The Hertfordshire Wheel Plough, "one of the best and strongest for most Uses." A, Plough-beam; B, Handle, Tail, Stilts, Hales or Staves; C, Neck or Share-beam; D, Earth-board, Mould-board, Brest-board, Furrow-board, Shield-board, etc.; E, Sheath; F, Share-iron; G, Coulter; H, Plough-pin and Collar-links; I, Plough-pillow and Boulster; K, Wheels. (Mortimer.)

The harvesters are made to cut 5-, 6-, 7- or 8-foot swaths, and 12 to 20 acres per day can be harvested with one of these self-binders. The 80,000,000 acres of wheat, oats, rye and barley grown in the United States make the self-binder an implement so necessary that it is found on almost every farm that grows 20 acres of grain. On some of the large farms there are as many as fifty self-binding harvesters, and as much as 600 acres of grain are cut in a single day. The machines require from three to four horses, and the tongue is often provided with a special truck which takes off neck weight and side draft.

Before the perfection of the present binder, it was thought by some that the binding of the grain and the handling of the amount of straw that was necessary to form a bundle was too laborious, and that there would be a quicker way of harvesting the crop by merely cutting off the heads. For this purpose was devised a machine called the header, which cuts a swath 12 feet in width. There are four horses hitched behind, which push the machine. The heads, when severed, are carried by endless aprons into large boxes mounted on wagons that are driven through the field beneath the spout of the machine. When a load is accumulated, another wagon quickly takes its place, while it is driven to some central place in the field and unloaded on a stack. From 30 to 50 acres per day can be harvested with one of these machines. The inability of preventing these stacks from spoiling when the season is wet or the grain is weedy, has prevented headers from displacing binders. Instead, the header-binder has been invented, which consists of the automatic binder attachment put on the header, which is made interchangeable with the elevator of the header so that the machine can be used as a header or as a binder, as desired. These machines are becoming common on the large farms in the West.

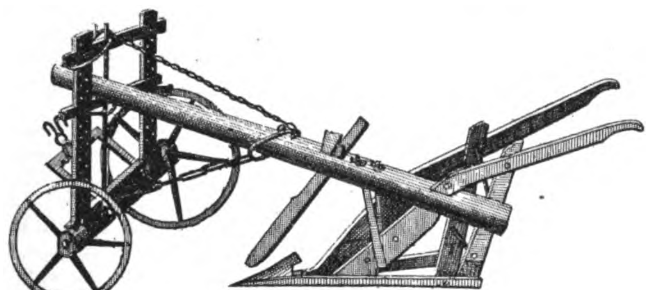


Fig. 238. "Portrait of a common Two-wheel'd Plough used in Berkshire, Hampshire, Oxfordshire, and Wiltshire, and in most other Counties of South-Britain." Jethro Tull, Horse-Hoeing Husbandry, third edition, London, 1751.

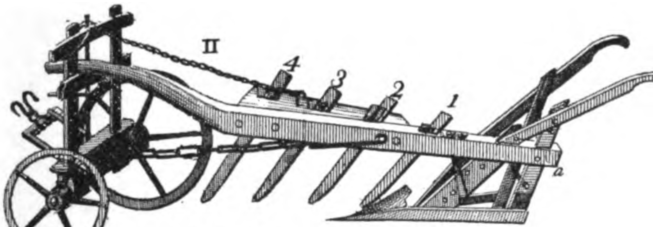


Fig. 239. Four-coulter plough. (Tull.)

The greatest labor-saver among harvesting machines, however, is the combined harvester and thresher, which is used extensively in the Pacific coast states, where rain does not occur in harvest time and where the stalks of grain are so stiff that they do not lodge. By the use of 20 to 30 horses or a steam traction engine, from 60 to 100 acres of grain may be cut per day. The machines cut a swath from 12 to 40 feet in width, thresh the grain and clean it, delivering it in sacks which are carried into piles and dumped the same as the bundles are delivered from a grain binder. The sacks are left in the field until harvesting is finished, when the traction engine and a train of wagons collect the grain and bring it to market.

We may recall the fifty years' progress in threshing machinery from the days of Pitts in 1850, with his horse tread-power and a separator that would thresh 50 bushels per day, to the modern threshing-machine, which comprises an 18- to 30-horse power, straw-burning steam engine,

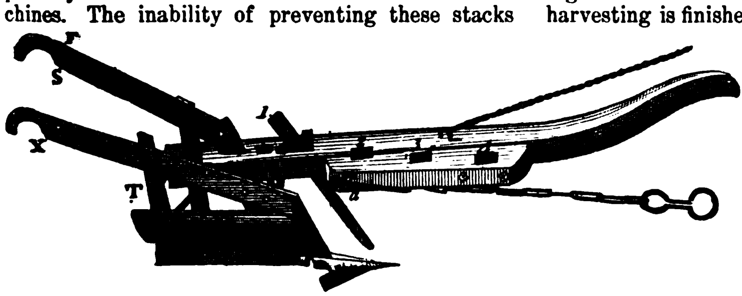


Fig. 240. "Shews the right-hand Side and upper Side of Four-coulter Plough." (Tull.)

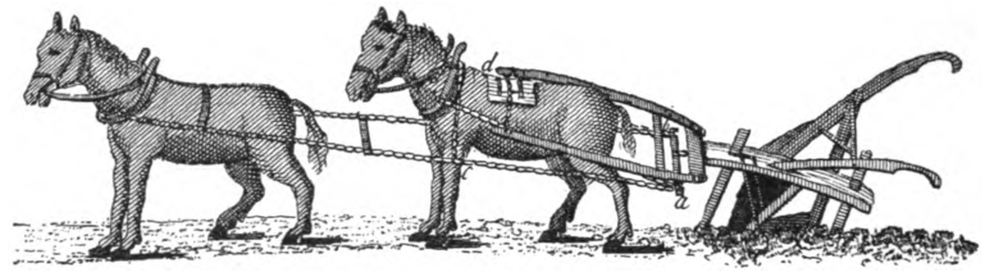


Fig. 241. "Shews the manner how the Hoe-Plough is drawn, and how the Traces are fix'd to it." (Tull, 1751.)

driving a self-feeding separator that will take grain as fast as two men can pitch the bundles to it, with the automatic self-feeder grain-weigher and sacker, and its wind stacker that blows the straw 50 feet away and automatically forms a semi-circular or cone-shape stack as desired. In the great wheat regions such threshing outfits are owned by all the large farmers, and they will thresh 3,000 bushels of wheat and 5,000 to 6,000 bushels of oats in a day.

The rice industry affords a good example of what may be done by modern farm implements and motive power in the development of agriculture. The rice-gatherers of other countries have used their cattle and primitive tools in preparing the soil and harvesting the crops, but the inability to flood their lands at the proper time and discharge the water at harvest time has made anything more than primitive methods absolutely impossible. American invention has wonderfully increased the ability of men to grow rice, and has made valuable large areas of worthless lands in Louisiana and Texas. In 1890, when the industry began there, land could be bought at $1 per acre. By the introduction of power-pumping plants which raise the water from wells and rivers, and by means of canals and dams, which distribute it over the fields in desired quantities, these have become the most productive rice lands in the world. By proper cultivation with modern implements, the lands produce, on an average, about 35 bushels per acre. This is harvested with the grain-binder and threshed with the modern threshing-machine. In 1904, these two states produced $13,000,000 worth of rice, and the land had increased in value to $50 per acre. It is estimated that Louisiana and Texas have 10,000,000 acres fit for rice culture. In South Carolina and Georgia, where the industry had formerly been very profitable, but where modern implements have not been introduced in rice cultivation, the planters are being forced to discontinue planting this crop.

One of the most difficult problems that the implement inventor has had is the tools for harvesting the corn crop. The work of gathering this crop is one of the most disagreeable on the farm, and, since over 100,000,000 acres of corn are planted yearly, the task is an enormous one. This acreage is equal to that of wheat, oats, rye, barley and buckwheat combined. As early as 1850 inventors began experimenting with machines to pick the ears from the stalks, and have continued their efforts ; but success has not been complete. Since 1890 machines have been made which successfully cut and bind corn into bundles and carry these into windrows with a bundle-carrier. The chief purpose for which the corn-binder is used is to cut corn to run through the shredder, used in filling the silo. Corn for this purpose is usually cut while it is still green, and the succulent juices are preserved by depositing it in an air-tight silo. This practice is increasing among dairymen. The corn is cut by the corn harvester, bound into bundles, and loaded on a wagon from which it is unloaded to the feed-cutter. It passes through this and is shredded into fine pieces which are forced by wind up into the silo.

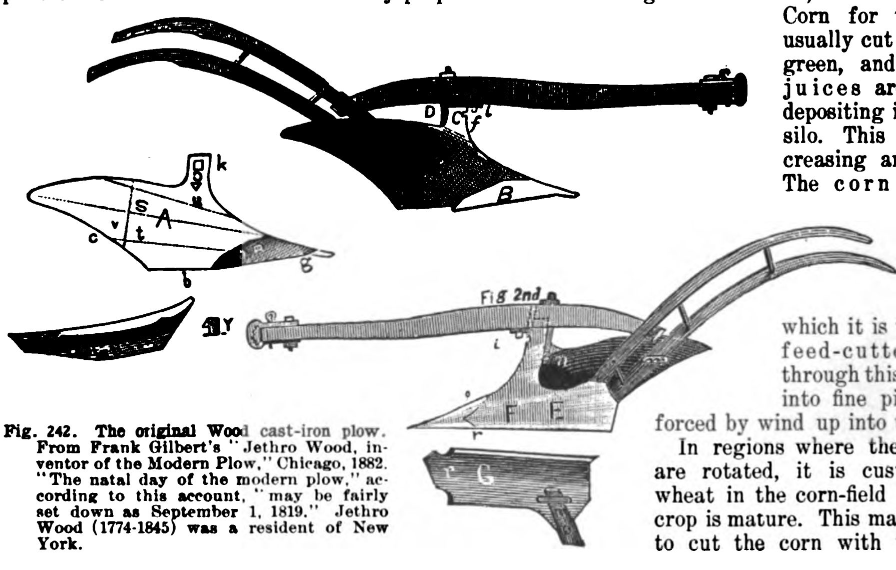


Fig. 242. The original Wood cast-iron plow. **From Frank Gilbert's** "Jethro Wood, inventor of the Modern Plow," Chicago, 1882. **"The natal day of the** modern plow," **according to this account,** "may be fairly **set down as September** 1, 1819." Jethro **Wood (1774-1845) was a** resident of New **York.**

In regions where the leading crops are rotated, it is customary to sow wheat in the corn-field before the corn crop is mature. This makes it necessary to cut the corn with the corn-binder and put the shocks in as few rows as possible. The farmer then goes into the field in the late fall and husks the corn by hand; or he hauls it home and runs it through the husker and shredder, thus saving the fodder as well as the ears.

The corn-binder requires one man and three horses, and three men to shock the corn. To reduce the man-power another machine, called a shocker, has been devised, which cuts the corn and delivers 100 hills or more on a revolving platform in a vertical position until a shock is formed. Then the machine is stopped, the tops tied and the shock lifted from the platform by means of a windlass and deposited on the ground at the side of the machine. The corn-binder can harvest with four men and a team from seven to nine acres per day, while the capacity with the shocker is from three to four acres. The huskers of large sizes will husk and shred corn from 12 to 15 acres per day.

When there are not sufficient cattle to consume the fodder, there is no object in cutting the corn; the ears are then gathered from the stalks either by hand or by the modern corn-picker, which runs along the row and snaps the ears from the stalks and passes them over a pair of husking rollers,

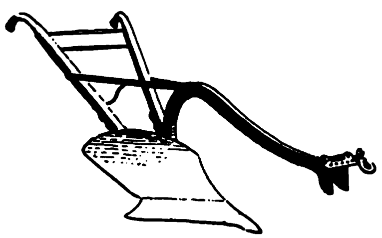


Fig. 243. The modern steel plow.

where they are husked; or they may be conveyed by an elevator directly into a wagon without being husked. Machines of this type with a driver and four horses for the machine and two teams and wagons to receive the corn, will pick from seven to nine acres per day.

Another kind of machinery which is rapidly aiding in improving agricultural conditions is the cream-separator. Hundreds of thousands of these machines are manufactured annually. The revolutionizing effect which the cream-separator has had on dairy farming can hardly be estimated. Thousands of farmers have gone into the dairy business who would never have done so without it. By its use for less than half an hour in the morning and evening, the farmer is able to increase his profits over the old cooling method of cream separation $10 per year for every cow he milks. The cream is delivered to the creamery, thereby lightening the work of the farmer's wife over old methods of making butter in the house. The milk can be used in feeding calves and pigs while fresh and sweet. Thus the cream-separator has in a great many cases been responsible for diversified farming and increased profits to the farmer. It has also been responsible for the introduction of the silo on many farms and the preservation of green and nutritious feed in the winter months.

Power.

The form of motive power on the farm is now in the transition period. In the past the draft animals have done practically all of the farm work, with the help of an occasional windmill for pump-

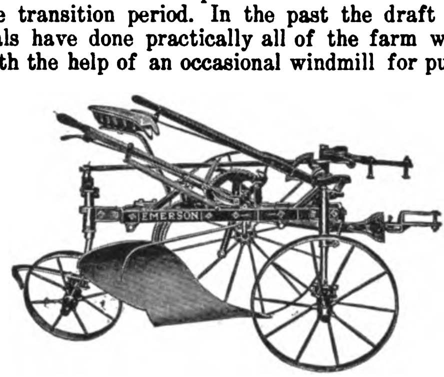


Fig. 244. A riding plow of the present day.

ing water. The gasoline engine is now rapidly finding favor as a farm motor, and its usefulness can be greatly extended to do much of the disagreeable work on the farm. This form of power is now applied to thousands of different kinds of work that twenty years ago were either done by man or beast or left undone. The price of gasoline, however, is rapidly increasing, and something must be found for internal-combustion engines. Consequently, in every country many minds are at work on the question of securing a satisfactory substitute for gasoline that can be produced as cheaply, the source of which shall be well-nigh unlimited. Gas can not be used by farm motors that have to be movable. Gas from a producer gas plant is an excellent substitute when large units of power are required, but for small farm power plants that require power only intermittently, the cost of installing the plant is prohibitive. The substitute for gasoline will have to be something in a fluid state that may be kept in bulk at every country store and be easily obtainable in small quantities, so that for automobile purposes enough may easily be carried for half a

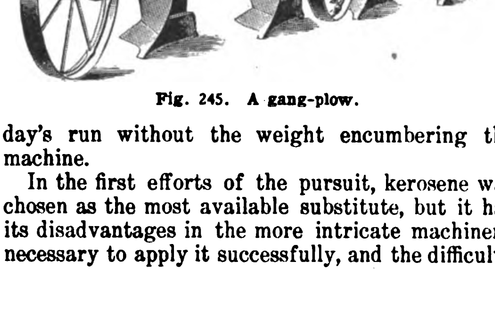


Fig. 245. A gang-plow.

day's run without the weight encumbering the machine.

In the first efforts of the pursuit, kerosene was chosen as the most available substitute, but it has its disadvantages in the more intricate machinery necessary to apply it successfully, and the difficulty experienced in securing its perfect combustion. Hope now turns to an article that has an inexhaustible source of supply, and which it is believed, when once thoroughly understood, will be an ideal substitute for gasoline. This article is denatured alcohol. It is ethyl alcohol combined with some rank poison that renders it unfit for use as a beverage. This adulteration does not affect its combustible and power-producing qualities. Already in Germany, France and other European countries it is extensively used as a power-producing agent, as a fuel in the internal-combustion engine. It will have several advantages over other forms of fuel, both for power, light and heat. It can be manufactured from the waste materials of the farm, such as small and unsalable potatoes, poor grades of corn and barley, and even waste corn stalks, beet pulp, and the like. Thus, the use of alcohol should benefit the farmer by providing a use for a great many waste materials and at the same time reduce the cost of motive power for farm work. [For a fuller discussion of power, see succeeding article.]

Fig. 246. Haying in the old time.

Economic questions.

With the advent of cheaper fuel for motive power, we may expect to find a traction internal-combustion engine of about 15-horse-power capacity, which will be able to do the work of a 5-horse team in the field in pulling the gang-plow, harrows, drills and cultivators; and it will also be able to furnish power for the small threshing-machine, the corn-shredder, cream-separator, and the numerous other stationary machines on the farm. In this way, the horse may be eliminated to a large extent and the number of hands required to operate the average farm be proportionately reduced. The farm hands, however, will have to be of a higher class, being able to repair and keep in order the various machines; and in consequence they will command the same pay and hours as is given men working in the cities and factories. The introduction of so many labor-saving machines necessitates a good working knowledge of the different kinds, and to this end a knowledge of the principles of mechanics.

Machinery has been a blessing to many farmers and a curse to others. Many persons buy more machinery than necessary; a few buy less than they need. Diversified farming may easily be overdone, for in order to grow successfully a large variety of crops, as potatoes, tobacco, sugar-beets, cabbage, corn and wheat, each crop requires different machinery. With the exception of wagons, buggies, cultivators, separators and powers, the larger part of farm machinery is idle eleven months of the year. To this must be added an expense for shed room, insurance and interest on the investment, while machinery in other lines of business keeps the wheels turning night and day twelve months in the year.

It is important to know when a machine is really profitable. There are some machines that a farmer can not afford to buy under certain conditions. One cannot look to the manufacturers for guidance in this matter. They are interested primarily in the selling of the machine. Just when a machine ceases to be profitable is not easy to determine. The answer can be approximated, however, by determining the cost of the machine, the cost of labor by hand, the cost of hiring another machine to do the work, and the feasibility of the various plans for performing the work.

When, for example, is it profitable to buy a grain-binder? The initial cost of a six-foot binder is $120. The interest on this sum per year at 6 per cent is $7.20. The average life of a grain-binder depends on the amount of cutting and the care it receives. With good care, it ought to cut 2,000 acres before it is worn out. Very few accomplish this much; but we may assume that the binder lasts ten years. This makes the cost for wear per year $12, and the total cost of a machine $19.20 per year, not including breakage and sheltering.

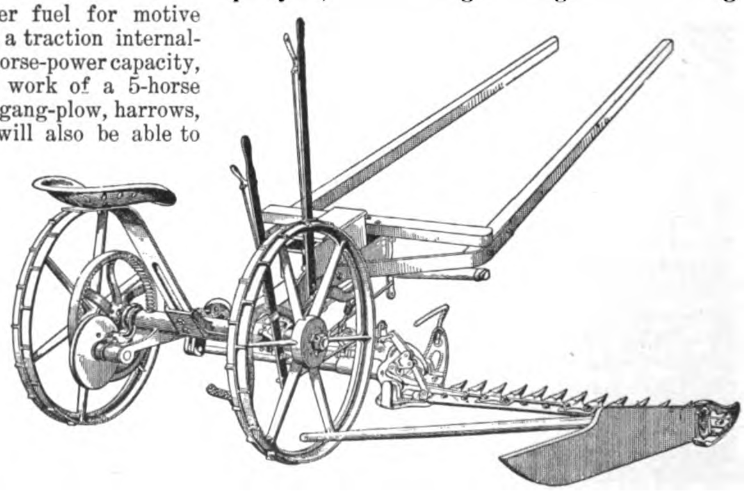


Fig. 247. Mowing machine of the new time. A one-horse vertical-lift mower.

It is now to be determined how much grain a man must cut to make it pay him to buy a binder rather than hire his neighbor to do the work. A man and team are worth at least $3 per day. If a man has 30 acres to cut, it costs him on an average 75 cents per acre, or $22.50 to hire it cut. It requires two days to cut the grain; so, if the man uses his own machine, it costs him $25.20, or $2.70 more than to hire it cut. Unless a man who has 30 acres of grain to cut is figuring on doing work for others with his machine, it will hardly pay him to buy a binder. He would, however, have the satisfaction of knowing that his grain could be cut at the right time and not be subject to loss from neglect after it is ripe, thereby reducing the risk. The question is also modified by the ease or difficulty with which hand labor is to be secured. For anything above 30 acres of grain it would no doubt pay a farmer to own his binder.

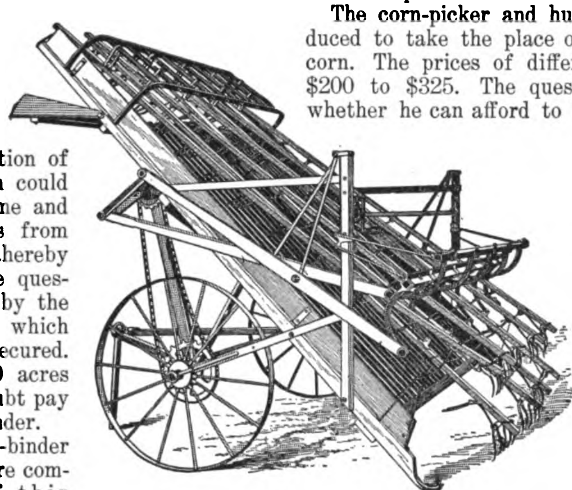


Fig. 248. Hay loader.

Again, with the corn-binder the question is still more complicated. The cost of this machine is the same as that of a six-foot binder, but the durability is much less. Eight years may be said to be the maximum average life of a corn-binder, making a cost of $15 per year. To this must be added $7.20 for interest, making a total of $22.20 per year. It is not often that a farmer cuts over twenty acres of corn. Three men will be required to shock after the binder, making a cost of $7.50 per day for labor and team. Twenty acres of corn is about three days' cutting with a machine; so the labor would amount to $22.50. The total cost of cutting with a machine would therefore be $44.70 for 20 acres. Men could probably be hired to cut corn by hand for 10 cents per shock or, at an extreme, $2 per acre. The cost of cutting 20 acres would then be $40, or $4.70 less than with the machine. However, it is more difficult each year to secure men to cut corn by hand at any price, and for this reason, if for no other, the corn-binder makes the farmer more independent of the labor problem.

The corn-picker and husker is now being introduced to take the place of hand labor in picking corn. The prices of different makes range from $200 to $325. The question for the farmer is whether he can afford to buy such a machine. It requires three men with teams to run it, or a cost for labor equal to $9 per day. It will pick from six to eight acres per day. The life of the machine is not yet determined, but is probably about the same as that of the corn-binder. The machine, with interest, will cost from $50 to $60 per year. For 30 acres of corn the cost would then be $36 for labor and $50 for the machine, or a total of $86. It will cost about $2 per acre to husk corn by hand, so that if a man who has only 30 acres of corn to pick can obtain the hand labor, it would probably not pay him to buy a corn-picking machine.

The manure-spreader may be similarly considered. The cost of the spreader is approximately $120, and its life about ten years. The cost will be the same as for a grain-binder, or $19.20. As the spreader unloads the manure it may be said to save one-half the labor, or do the work of one man. Then, in order that it may be profitable, a farmer must have enough manure to haul so that the labor of a man to handle it amounts to $19.20, and the use of the machine $19.20 more. Or, in other words, he must have $38.40 worth of hauling

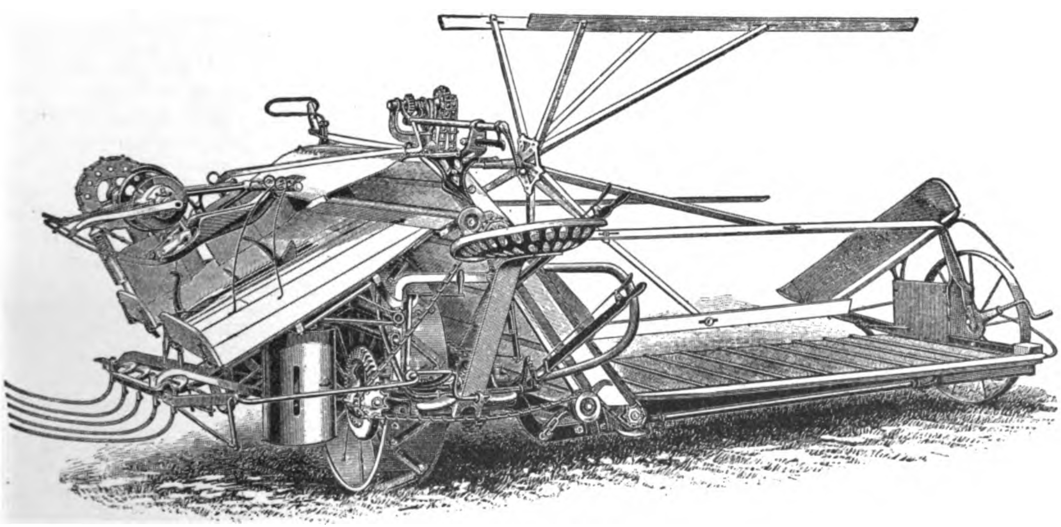


Fig. 249. A modern self-binding reaper.

for one man. Counting wages at $1.50, he must have work for one man for twenty-five days. Or, if a laborer can haul eight loads a day, he must have 200 loads of manure to make the spreader pay. Of course, the better work done by the spreader, and the less time required to use the team must be considered; but this example serves to show that there is a limit at which it is profitable for a farmer to buy machinery.

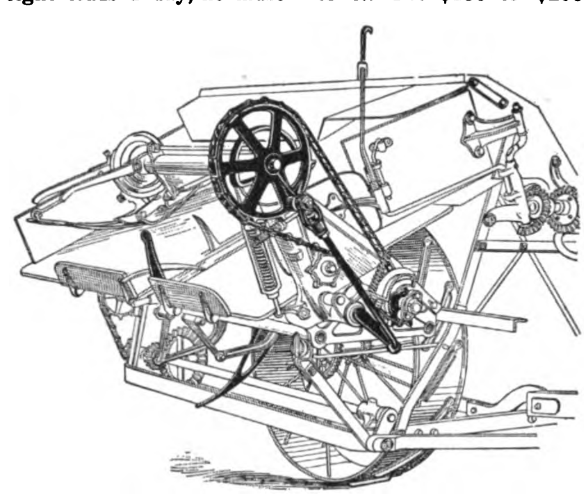


Fig. 250. Part of a reaping machine (eccentric wheel at rest) to illustrate the high degree of complexity of modern farm machinery.

The machinery equipment.

A well-regulated farm of 160 acres, all or mostly tillable, that raises corn, grain, hay and stock, should have for its successful operation at least the following implements, which cost approximately the sums named:

One grain-binder	$120 00
One mower	45 00
One gang-plow	50 00
One walking-plow	12 00
Two cultivators	40 00
One disc pulverizer	25 00
Two farm wagons	100 00
One smoothing harrow	18 00
One corn-planter	35 00
One seeder	20 00
One manure-spreader	120 00
One hay-loader	45 00
One hay-rake	20 00
One light road wagon	60 00
One buggy	75 00
	$785 00

A farmer is always safe in selecting machinery and implements from manufacturers who have a reputation for making high-grade goods. The cheap implements, buggies and cream-separators are usually dear at any price. Therefore, the farmer should buy the best machinery and take good care of it. For $150 or $200 a very convenient and attractive tool shed 40 feet long, 20 feet wide and 10 feet high may be built. By careful planning, a building of this size can be made to shelter all the foregoing machinery very satisfactorily, especially if a floor be provided on a level with the eaves, by which means considerable room can be made by taking some of the implements apart, and removing parts from some of the larger machines, and storing them above. Let us assume that a man starts farming with $785 invested in implements, and that, if sheltered and well-cared for, they will last ten years, and if not sheltered, five years. If the implements stand out in rain and wind, it costs $785 more to purchase a new set at the end of five years. The compound interest on this amount for five years, at 6 per cent, amounts to $265.51; or the extra amount paid for machinery, with its accrued interest, equals $1,050.51. If the tool shed costs $200, the compound interest on this amount for ten years, at 6 per cent, will be $158.14; so the shed may be considered to cost $358.14. After paying the expenses for the shed, it leaves us at the end of ten years a balance of $692.37 in favor of housing the machinery; and the shed is perhaps good for ten years more. This does not take into account the extra cost of repairs on machines because of lack of care, and the effects on the temper of the man who uses them.

The care of machinery.

The average life of a grain- or a corn-binder, mower or plow should be from 12 to 15 years.

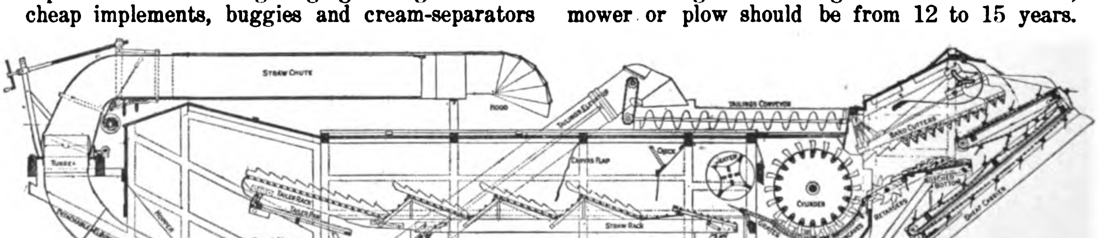


Fig. 251. A modern separator, with 20-bar cylinder, wind stacker and feeder.

Drills, seeders, rakes, cultivators, etc., last 10 or 12 years; with good care they should last 20 or more. No merchant or manufacturer would expect to make a profit unless he exercised the strictest economy and took the best care of all his equipment. Yet many farmers buy expensive implements, costing as high as $100 or more, and give them no care whatever. Every farmer should have a repair shop, with forge, anvil, vise, drill, files, etc.; a work-bench with saws, plane, brace, and a good assortment of auger-bits, square, hammers, wrenches, pincers, tools for mending harness, an assortment of bolts, rivets, washers and nuts, a thread-cutter and taps, and lumber of different kinds for repairing. With an outfit of this kind, that would cost not over $50, a farmer can do much of the repairing that would otherwise necessitate many trips to town.

Before spring work begins, sharpen the drag-teeth, drill- and cultivator-shovels, disc-harrow and plow-lays. Go over each piece with a wrench, tighten loose nuts and put in a bolt, nail or screw where needed. Tools of this kind, when put in the shed after the season's work, need to have the bright parts covered with grease of some kind to prevent rusting. Every implement should be looked over carefully before it is used, to see that all moving parts work freely. The mower knives should be kept sharp; put new ledger-plates on the guards when badly worn; drive the tops down if the space is too wide, so that the sickle will run close. The binder should be thoroughly cleaned up and any badly worn parts replaced with new ones; loose slats on canvas, straps and buckles should be fixed; one or two extra reel arms and slats should be on hand in case of breakage; a few extra bolts and a small alligator wrench with a monkey-wrench should be put in the tool-box. See that all working parts are oiled. The windmill is usually the most neglected piece of machinery on the farm, being seldom oiled until it squeaks.

It often happens with new machines that moving parts do not work freely because of paint in the bearings. This may be overcome by using a good supply of half kerosene and half machine oil on the bearings the first day the machine is used.

The saving which would come to the farmers of the country by extending the life of each machine one year would be an immense addition to the annual profits. This saving can be realized and augmented by the greater efficiency which comes from expert care and management. A season without shelter detracts more from the value of farm machinery than the wear caused by the use during the same season. It is well known that iron and steel, when exposed to the rains, undergo a chemical change, and rust is formed which causes gradual destruction of these materials and interferes greatly with the working of the machines. Much valuable time is lost by this and less efficient work is done. A machine is no stronger than its weakest part; therefore, the great necessity of so caring for it that none of its parts become weakened by unnecessary exposure is evident.

FARM MOTORS

By *P. S. Rose*

The motors used for agricultural purposes may be classified as follows, and it is proposed to discuss the classes in order: (1) animal motors; (2) steam engines; (3) internal-combustion engines; (4) hot-air engine; (5) windmills; (6) water motors; (7) electric motors. All except the last named are prime movers,—that is, they derive their energy directly from natural sources without the intervention of other mechanism. Some of these depend on chemical action for their motive power and may properly be called chemical engines. The food eaten by animals undergoes chemical changes during the process of digestion and assimilation, and in some way, not yet well understood, is transformed into mechanical energy which manifests itself in the various bodily movements, both voluntary and involuntary, and in the power to do work. The fuel supplied to the internal-combustion engines likewise undergoes chemical change in uniting with the oxygen of the air, and is first changed into heat energy and then into mechanical energy through the agency of some fluid medium, such as steam or gas. Windmills and water-wheels utilize the kinetic energy of masses of air or water, by arresting their motion, while electric motors depend on a dynamo to supply them with energy, which in turn must be actuated by one of the prime movers above mentioned.

Animal motors.

The most numerous, most important, and mechanically most complicated of all the motors the farmer has to deal with, are the animal motors. Viewed simply as a machine, the animal is wonderful. It feeds itself, maintains itself, controls itself and reproduces itself, four distinct things that cannot be done by any machine that man has ever made. Besides, all things considered, it is more efficient mechanically since it yields greater returns for the fuel energy supplied than any other machine. Looked at simply as a piece of mechanism, an animal consists of a jointed framework of levers held together with muscles and ligaments; a motive equipment of muscles arranged in opposite pairs attached to this framework; a power-generating apparatus, consisting of the digestive organs; an excretory system to carry away the waste products; a controlling mechanism consisting of brain and nerves; a system of perfect lubrication for all moving parts; and lastly, a proper housing or covering, consisting of the skin and hair, to protect the entire apparatus from outside injury.

The most important animal motors in America are the horse and the mule. In 1900, there were 15,517,052 work horses on the farms and ranges of the United States, and 2,759,499 mules, making a total of 18,276,551 work animals, or an average of 6.3 work animals for every 100 acres of cultivated land in the country. Assuming that each beast is able to do two-thirds of a horse-power of work, which is given by all authorities as a fair estimate, then the total available animal horse-power in the United States in 1900 was 12,184,366, being an excess of 184,285 horse-power over that used in all manufacturing enterprises in the same year.

The maximum draft of a horse traveling at the rate of $2\frac{1}{2}$ miles per hour is given by Professor King as equal to half its weight. At this rate, a 1,600-pound horse is capable of doing a maximum of $5\frac{3}{8}$ horse-power work. Such effort, however, is too severe to be maintained for more than a few minutes at a time. For continuous work of ten hours per day, a horse is not capable of drawing more than one-tenth to one-eighth of its weight. On this basis a 1,600-pound horse can do 1.06 to 1.33 horse-power and a 1,000-pound horse .67 to .83 of a horse-power. If a horse travels faster than $2\frac{1}{2}$ miles per hour, or at a slower rate, his pulling capacity decreases or increases in proportion to the change in speed. Weight is the principal factor in determining the power of a horse, but this factor is influenced to a considerable extent by the conformation of the skeleton and the distribution of the weight.

The unit for measuring work is the foot-pound, and may be defined as the overcoming of one pound of resistance through a distance of one foot, or, as the lifting of one pound one foot. A horse-power is equal to the accomplishment of 33,000 foot-pounds of work in one minute, and is the customary unit applied in designating the power of a motor. The term "horse-power" is an abstract mathematical unit and bears no fixed relation to the amount of work a horse is capable of doing. In fact, few horses are able to do more than two-thirds of a horse-power of work for any considerable period, though their maximum effort for short periods may be greatly in excess of this amount, as stated above. It has been found by experiment that the average-sized man can do one-tenth to one-eighth of a horse-power of work, covering the usual working day of eight to ten hours. For a few minutes he can do half a horse-power, or a full horse-power for a few seconds.

In changing from animal to mechanical power, experience would seem to indicate that these statements in regard to the power of animals are incorrect, inasmuch as it requires a motor of six or seven horse-power to do the work usually performed by three horses in handling farm machinery. The reason for this apparent discrepancy is found in the fluctuations of the load. On an average, the load may be only two or three horse-power, but occasionally runs as high as six or seven. The horse can exert enough additional power for short intervals to get over these high places, while an engine, unless large enough to meet maximum requirements, will get stalled. Therefore, in replacing animal power with mechanical, it is best to install an engine capable of meeting the maximum requirements of the work in hand. In addition to this, there must be taken into account the amount of power required for traction if the engine is self-propelling.

Professor King states the amount of power for hauling as follows: "The hauling of two tons on a wagon, at the rate of $2\frac{1}{2}$ miles per hour, under the varying conditions on the farm, requires the team to develop energy at a rate ranging from 1.13 horse-power to as high as 4.98 horse-power." In stubble-plowing, when the soil is in medium condition, Professor King finds that two 1600-pound horses find their full capacity for work taxed by the 14-inch plow cutting 4 to 5 inches deep, while a team of 1200-pound horses find sufficient work in hauling a 12-inch plow cutting the same depth of furrow.

An illustration of a tread-power is shown in Fig. 252, and is sufficiently plain to need no detailed description. These powers are made in various sizes—from those small enough to be operated by dogs, sheep or goats, to mills large enough for three horses. The dog and sheep powers are used

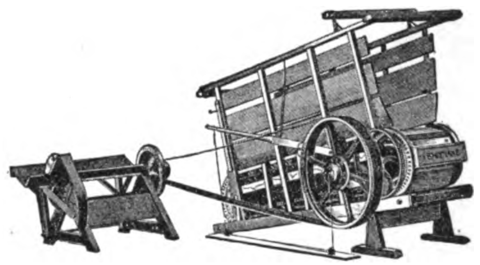


Fig. 252. One-horse tread-power attached to a saw-table.

for churning, running cream separators and other work that is not very heavy, while the large powers in which horses or mules are worked are utilized for sawing wood, grinding feed, threshing, pumping and almost any other purpose for which power is required on the farm.

When a horse is put in a tread-power he performs work by lifting his weight against the force of gravity. The steeper the incline the greater will be the effect of gravity, the faster the horse will be obliged to travel, and, consequently, the more work he will perform. It is customary to give the bed of the machine a pitch of one foot in four, which requires an animal to lift one-quarter of his weight constantly; this is a considerably greater effort than an animal should be expected to make. It will thus be seen why tread-powers are generally considered so efficient. While it is true that a horse can do more work in a tread-power than in almost any other way, it is generally done at the expense of overwork. Because of the large extent of bearing surface in these machines, considerable care must be exercised in lubrication to keep them in good order.

A sweep-power is the subject of illustration in Fig. 253. These machines are made in sizes requiring one to fourteen horses. Before the traction engines came into use they were the principal power used in threshing grain. They are still used for threshing in some sections of the country where grain-raising is not practiced to great extent, and by farmers who do not feel able to invest in steam-power. They are also used in well-driving and for general work about the farm for which a cheap, portable power is required. The sweep-power is not a very efficient machine, because, as will be seen from an inspection of Fig. 253, the line of draft cannot be at right angles to the sweep, as it must be in order to render the highest percentage of draft available. When the line of draft makes an angle of less than 90° with the sweep, a certain component of the draft, which increases as the angle, becomes smaller, acts only as pressure against the bull-wheel and produces friction instead of being transformed into useful work.

Professor Thurston says: "The daily work of the animal, at its best, depends on its exact accommodation to most favorable conditions for the development of the best work of the individual, and on its size, natural strength, endurance and spirit. These qualities in turn are dependent on the breed, the state of health and the general condition of the animal, its food, its environment, the weather, the climate and the adaptation of its load to its habit and training."

The efficiency of the animal machine, considering only external work as the product, and taking the total heat value of the food as unity, has been found to be about 20 per cent. Recent experiments by Professor Atwater show an average efficiency for man of 19.6 per cent. The heat efficiency of the best steam engines is about the same, while the average falls below 10 per cent. Gas engines give somewhat better results, ranging from 18 to 25 per cent.

When it is considered that the animal motor shows about as much efficiency as the best heat motors man has been able to make, over and above what is necessary for bodily maintenance and reproduction, the truth of the statement made in the beginning, that animal motors show the highest efficiency, at once becomes apparent.

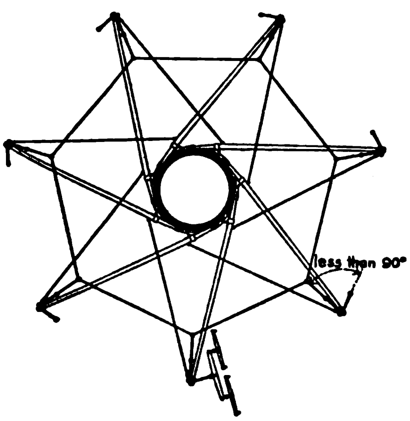


Fig. 253. Top view of 14-horse bull-wheel with sweeps, braces, equalizers and one set of doubletrees attached. The line of draft is less than 90°, resulting in the loss of a small amount of power.

The steam engine.

The steam engine is a machine in which the elastic property of watery vapor or steam is used to produce motive force. Every steam engine consists essentially of two parts—the boiler in which the steam is generated and the engine proper. In stationary plants the boiler and engine are separate mechanisms, connected by a steam-pipe, but in most steam engines used for farm purposes the engine and boiler are combined in one machine, the engine being bolted to the boiler as a foundation. The principal parts of the engine proper are the cylinder, piston, steam chest, valves, connecting rods, crank, fly-wheel, eccentric and governor. The cylinder and steam chest are usually cast together and contain the piston and steam valves, which combination constitutes the most important working parts of an engine. Since these parts are necessary to a correct understanding of an engine, they are made the subject of illustration, Fig. 254.

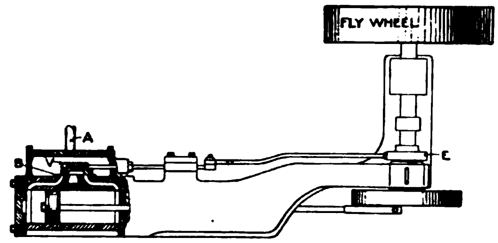


Fig. 254. Horizontal view of a steam engine.—A, steam-pipe; B, exhaust port; E, eccentric; V, distributing valve.

Briefly, the action of the steam engine is as follows: Steam flows from the boiler through pipe A and keeps the steam chest full of steam. The valve, V, which receives a small lateral motion from the eccentric, E, on the main shaft, distributes the steam to the cylinder, causing the piston to move backwards and forwards, giving a rotary motion to the crank. With the parts in the position shown in the figure, steam will flow past the left edge of the valve to the left side of the piston, causing it to move toward the right, while at the same time the steam on the right side of the piston, remaining from the previous stroke, is free to escape through the right-hand port, up through the hollow part of the valve and out to the air through the exhaust port B. Just before the piston reaches the end of its stroke to the right, the eccentric, which is in advance of the crank, reverses the position of the valve and admits steam to the opposite side of the piston, causing it to move toward the left. The heavy fly-wheel carries the engine over the dead points at the ends of the stroke, while the governor, situated on the steam-pipe, regulates the steam supply in accordance with the speed of the engine and the work it has to do.

Steam engines used on the farms in this country are of two general styles, viz., portable and traction.

Portable engines are usually of the simplest form, bolted to either a horizontal or an upright boiler, the whole mounted on skids or trucks, and are drawn from place to place by horses. Portable engines are used comparatively little for farm work at the present time. In 1900 it was estimated that not more than 10 per cent of the steam engines used on the farm were of this type, while at the present time, 1906, the figure is probably nearer 5 per cent.

The traction engine was used extensively in England before its utility was generally recognized in this country. On the small farms in the eastern and middle sections of the country, there was until a few years ago no particular demand for power other than could be supplied by the animals on the farm and an occasional portable engine. But with the opening of the West all these conditions were changed. The farms were larger, animal power was scarce and expensive, all the available horses were needed to handle the bundles and straw, and a demand arose for an engine especially adapted for threshing purposes that could not only propel itself, but also haul the water-tank, fuel-tender, thresher and cook-car. In fact, the grain-farms of the West as they exist today would not be possible but for the advent of the traction engine and other improved machinery.

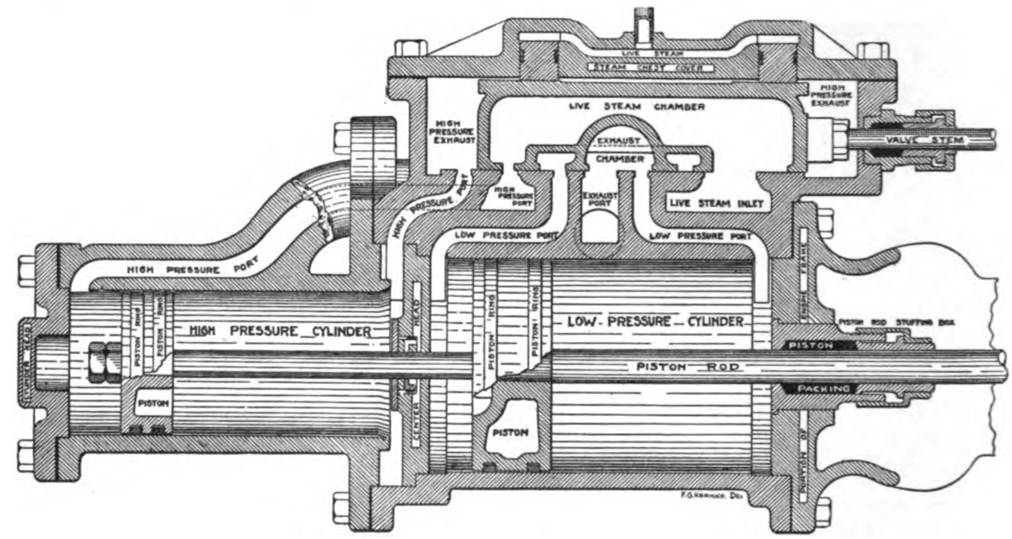


Fig. 255. One of the leading types of tandem compound traction engine cylinders.

Traction engines may be classified as simple single-cylinder engines, double-cylinder engines, tandem-compound and cross-compound engines.

Until a few years ago, single-cylinder engines were the only ones built, it being thought that farmers were incapable of taking care of the more complicated double or compound types. The demand for better and more economical engines, together with hard business competition, has resulted in many improvements in traction engines in the past dozen years, with the result that the last three types have been added. Compound engines of either type are more economical than simple engines, because they utilize more fully the expansive power of the steam (Fig. 255). Double-cylinder engines are used very largely for plowing and heavy road work. The chief advantages of this type of engine over the simple- or tandem-compound is that it is a better-balanced engine, having a steadier motion and causing no trouble from getting on dead center. Cross-compound engines, besides having the same advantages, are said to be more economical in the consumption of fuel and water.

The work traction engines are called on to perform includes threshing, plowing, ditching, road-making, grading, freighting, pumping, grinding feed, sawing wood, and so on. The principal uses, however, to which they are put are threshing, plowing and freighting. In the northwestern wheat states they often thresh 3,000 to 4,000 bushels of grain per day.

In the past five or six years steam-plowing has come into general favor all through the middle and western parts of the United States and western Canada. When the fields are large and comparatively few turns are necessary, plowing can be performed more cheaply by steam than by horses. In the northern parts of the country, the greater speed with which the work may be done and the short seasons which necessitate doing the work very rapidly, are some of the factors that have

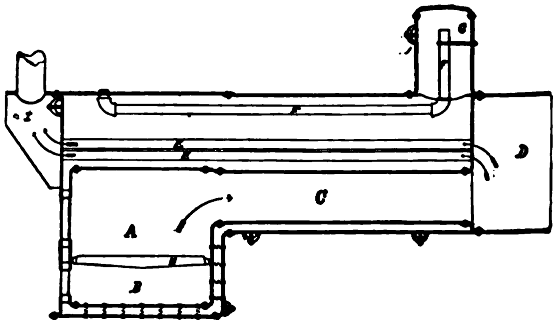


Fig. 256. Outline of a traction engine boiler. Fire-box is at A, into which the fuel is fed; the flame passes forward through the large main flue (C) and also through six 2¼-inch direct flues, and then into the combustion chamber (D). From this point the flame passes through the return flues (E) into the smoke-stack (I). Coal, wood or straw burner.

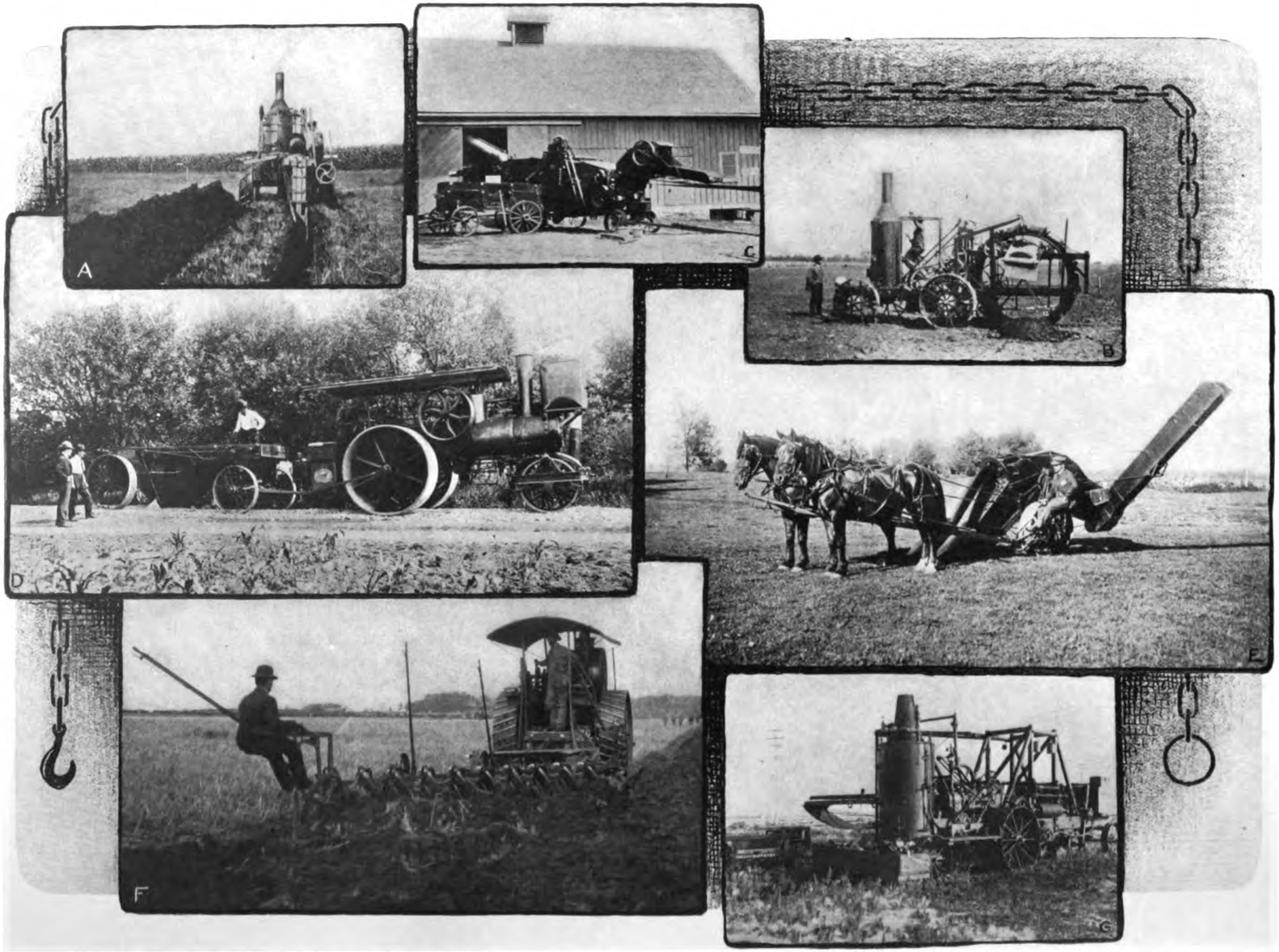


Plate XV. Types of heavy agricultural machinery. A, B, tile ditching machine; C, threshing separator; D, traction engine and crushed-stone wagon for road-making; E, corn picker; F, steam plowing outfit; G, ditching machine for open ditches led to the general adoption of steam-plowing, especially on the large farms. With the powerful engines now in use, it is possible to plow 30 to 60 acres per day. It usually requires three men and a team to take care of the outfit, an engineer, fireman, and a man and team to haul fuel and water. In ordinary stubble-plowing, when the ground is in good condition, 100 pounds of bituminous coal per acre is a fair estimate of the quantity of fuel required. In California, where steam-plowing has reached its greatest development in this country, the estimated cost per acre is 25 cents to $1, depending on the character of the soil, price of fuel and wages for men.

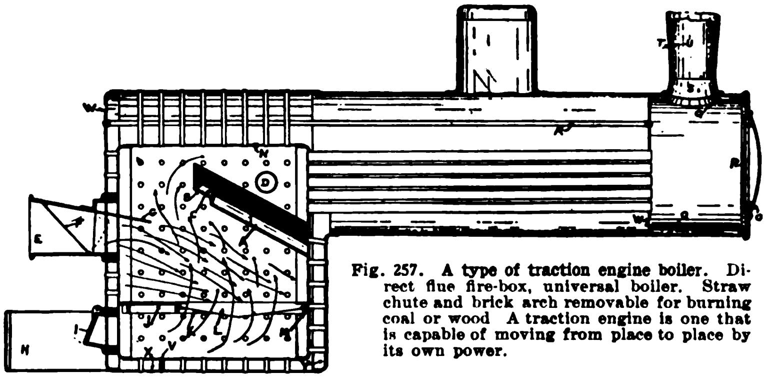


Fig. 257. A type of traction engine boiler. Direct flue fire-box, universal boiler. Straw chute and brick arch removable for burning coal or wood. A traction engine is one that is capable of moving from place to place by its own power.

The area suitable for steam-plowing in the United States includes the larger part of California, parts of Oregon, Washington, Utah, Nevada and Idaho on the Pacific slope; North and South Dakota, Colorado, Kansas, Nebraska, Texas, Oklahoma, Indiana, Missouri, Iowa, Illinois, and most of the Canadian Northwest.

In this country, the plow is hitched directly behind the engine and the whole outfit is propelled across the field to be plowed. In England and on the continent of Europe where steam-plowing is practiced, two methods are in vogue. The first method requires two engines stationed on opposite sides of the field, each equipped with a winding drum which operates a cable for hauling the plows back and forth across the field. In the second method, an anchor takes the place of one of the engines, and is so arranged that it moves automatically along the head-land when the plows make a trip across the fields. The plow carriage, operated by means of an endless cable, is arranged with a double set of plows, on opposite sides, so that when one set is in the ground the other is tilted out. These outfits, with their special plows and cables, are more expensive than the American, and are not capable of doing so much work.

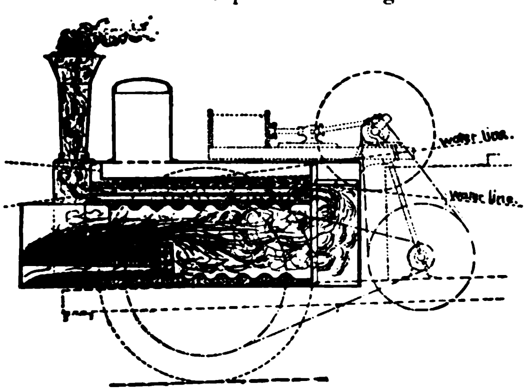


Fig. 258. A traction engine boiler showing the engine in place and arrangement of gearing.

An interesting adaptation of the traction engine occurs in rolling the tule lands of the Sacramento and San Joaquin valleys of California, preparatory to plowing. The main wheels are 9 feet in diameter, with 16 feet face, while the steering wheel is 6 feet in diameter and 5 feet face. This roller settles the ground 6 to 20 inches, and water is on the large wheels continually.

In operating combined harvesters on the Pacific coast, traction engines enable the work to be done at a very rapid rate and very cheaply, running as low as 40 cents per acre. The grain is cut, threshed, recleaned, and sacked in one operation at the rate of 75 to 100 acres per day.

In the matter of steam economy, the best grades of traction engines compare favorably with stationary engines of similar design, 25 to 35 pounds of steam per rated horse-power per hour being their usual performance.

The majority of traction engine boilers are of the horizontal pattern, with flues 2 to 2½ inches in diameter. Figs. 256, 257 and 258 illustrate the leading types. The average amount of heating surface per rated horse-power is 11⅓ square feet, while the average grate surface is one-third of a square foot. All traction engine boilers depend on induced draft for forcing the fire, secured by turning the exhaust up the chimney after the manner of locomotives.

The service required of traction engines is of a very exacting nature. They are subjected to the severe shocks and strains of rough country roads, to all sorts of weather conditions, to the evils of bad water and incompetent engineers. When used to drive machinery they are seldom carefully adjusted to the work. Engines of this class must also burn whatever kind of fuel is available, and consequently must be

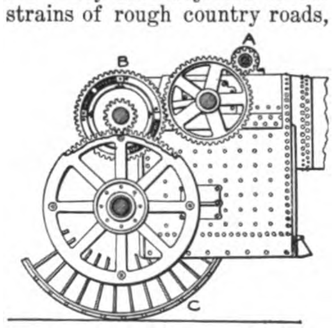


Fig. 259. Driving gear for traction engine. A, main driving pinion; B, differential gear, showing spiral springs to relieve shocks on rough roads; C, main drive wheel.

built strongly, have an elastic construction, and be free from all delicate adjustments. The fuels vary in different parts of the country. Wood is used where it is still cheap, straw in the wheat-raising belt, oil in parts of Texas and on the Pacific coast, and coal in other parts of the country.

The power is generally transmitted to the drive-wheels by means of spur-gearing, but in a few engines a combination of spur-gearing and chain-gearing is used. The elastic construction necessary in engines of this class is secured by spring-cushioned gears and spring connections between parts where heavy shock is likely to occur (Fig. 259). The driving-gears are usually connected with the main shaft by a friction clutch, though sometimes a positive clutch is used in double engines. All traction engines are made reversible, to accomplish which several devices are used. The link-reverse is the oldest and best known, while the radial arm-gear and shifting eccentric-gear are also extensively used. The reverse-gear not only controls the direction of rotation of the engine, but also plays an important part in the economy of its operation when properly handled, as by it the cut-off of steam in the cylinder can be adjusted to suit the load.

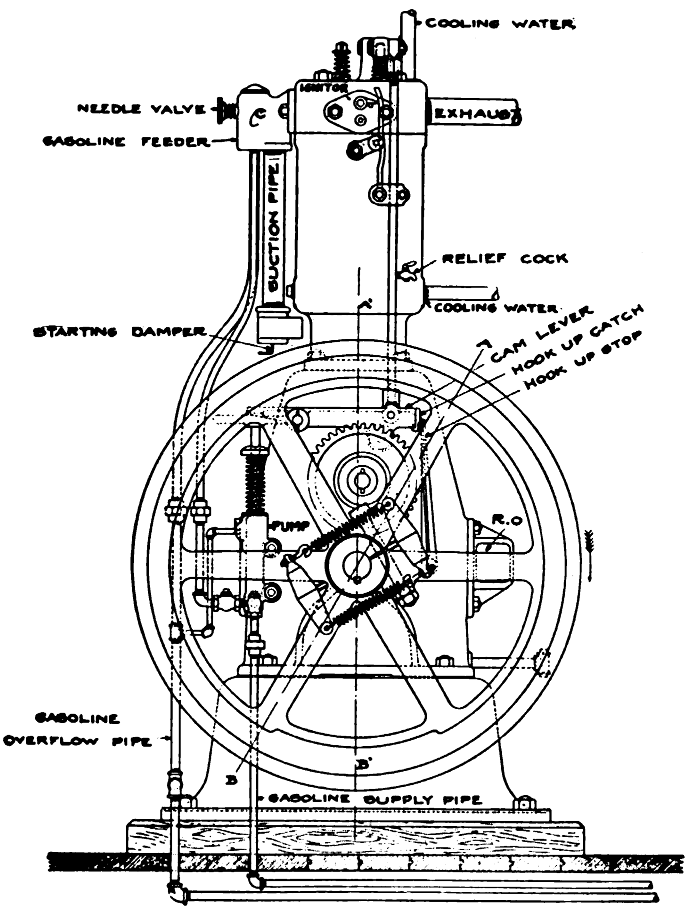


Fig. 260. Elevation of a vertical three horse-power four-cycle gasoline engine.

According to the Twelfth Census, in the year 1900 there were 31 establishments in the United States engaged in the manufacture of traction engines. Their total output for that year was 6,132 engines, valued at $6,385,026. Besides this, there were reported 130 road-rollers, which are only another form of traction engine, valued at $130,000.

The average life of the traction engine in the northwestern states, when it receives unusually hard usage and is left out-of-doors all the year round, is between seven and eight years. When the engines are housed in winter and taken care of, they last 15 to 20 years.

Internal-combustion engines.

Under this denomination are included gas, gasoline, kerosene, crude-oil and alcohol engines. All of these engines work on the same principle and are nearly identical in construction, only slight modifications in design being necessary to adapt any of them to the different fuels. In each case the fuel is first converted into a gas or vapor, mixed with the right proportion of atmospheric air, and then burned directly in the engine cylinder. Gasoline vaporizes at ordinary temperatures and is converted into gas by spraying it into a rapidly moving current of air. Such fuels as kerosene and crude oil, however, vaporize only at high temperatures and must be passed through a hot chamber before they reach the engine cylinder. This hot chamber is connected directly with the cylinder and is heated by the burning gases during each explosion.

Internal-combustion engines, called also gas engines, or explosive engines, may be divided into two forms, depending on their structure and manner of operation, called four-cycle and two-cycle engines. The four-cycle engine operates as follows: 1. On the first outward stroke of the piston a charge is drawn into the cylinder. 2. This charge is compressed to 40 to 90 pounds per square inch on the return stroke and ignited before the stroke is completed. 3. The piston moves outward the second time under the impulse of the explosion. 4. On the second return-stroke the exhaust-valve is opened and the burnt gases are expelled. Four distinct operations and two revolutions of the fly-wheel have been required for one explosion in this type of engine, and hence the name four-cycle. In the two-cycle engine these four operations take place in one revolution, allowing an explosion to occur on each outward stroke of the piston instead of on alternate strokes, as in the four-cycle type.

The temperature of combustion in the gas engine cylinder varies in different types of engines, and is dependent on the kind of fuel, the character of the mixture and the degree of compression. In gas engines the temperature varies from 2,200° to 3,000° F., temperatures high enough to melt the cylinder walls if some provision, such as a water- or oil-jacket, were not made to carry off the excess heat. The working medium, after explosion, in any explosive engine is a mixture of watery vapor, nitrogen and carbon dioxid gas. These are the products of combustion. The high temperature to which they are raised causes a rapid rise in pressure, amounting in any ordinary gas engine to 200 to 300 pounds per square inch at the beginning of the stroke. Either too much or not enough fuel for the quantity of air makes a weak explosive mixture, causes low temperatures, low pressure, lack of power and poor economy.

The first internal-combustion engine was a gunpowder engine invented in 1678 by the Abbé de Hautefeuille. In 1680, Huygens also invented a gunpowder engine. Neither of these inventions was of any practical use. In 1691, John Barber, an Englishman, invented the first hydrocarbon engine. From that time on very little of practical value was done in this field of investigation until 1860, when Lenoir, a Frenchman, invented the first practical form of gas engine. In 1862, Beau de Rochas brought out his four-cycle compression engine, which was further improved by Otto and Langen, two noted German engineers. George Brayton, an American, in 1872 invented a hydrocarbon engine that was the first internal-combustion engine to meet with commercial success in North America. This engine was superior to the Lenoir, but inferior to the Otto which succeeded it. Since then many inventors have entered the field, and this type of engine has been improved until it has now come to be the most formidable competitor of the steam engine.

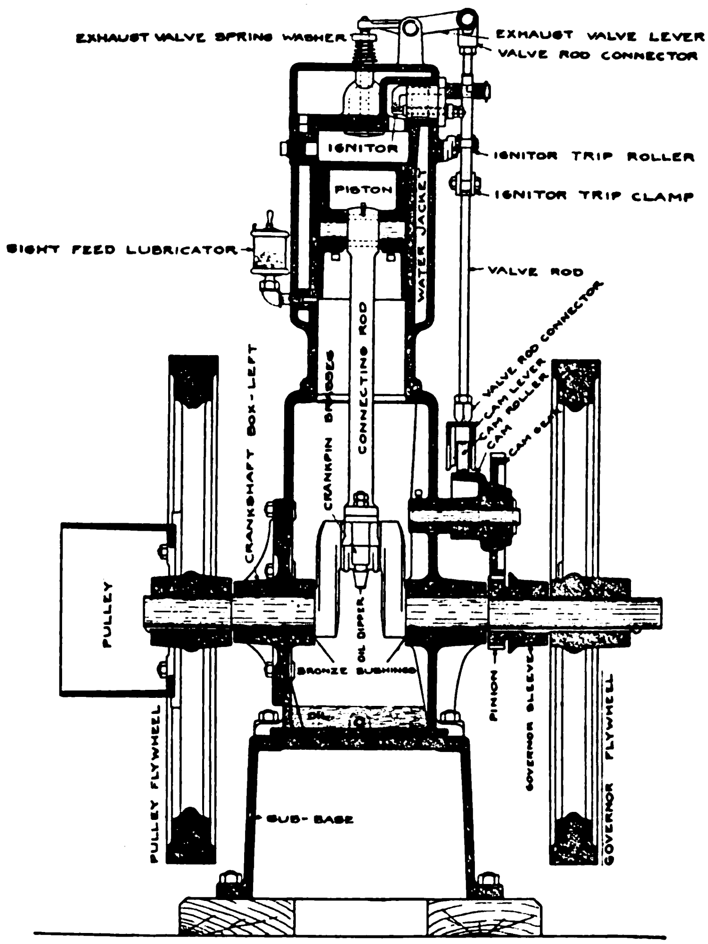


Fig. 261. Section of the vertical three horse-power four-cycle gasoline engine shown in Fig. 260.

Up to within a few years ago, gas engines were made only in small sizes, ranging from 1 to 100 horse-power. But at the present time they are built in units as large as 3,000 horse-power, thus not only competing with the steam engine for farm work and small power plants, but for large power plants as well. Gas engines adapted to burn the vapor of gasoline are called gasoline engines.

Gasoline engines are built in both the horizontal and vertical styles for farm work. The one that is made the subject of illustration, Figs. 260, 261 and 262, is a three horse-power vertical engine designed expressly for the agricultural trade. It is a four-cycle engine and operates as follows: When the piston starts on its first downward stroke a vacuum is formed in the cylinder. Consequently, air under atmospheric pressure rushes through the suction pipe, Fig. 260, takes up a charge of gasoline vapor in passing through chamber C, opens the intake valve against the pressure of the coiled spring and enters the cylinder. On the return stroke this charge is compressed and ignited electrically at the proper moment. Ignition is accomplished through the cam-gear, cam, ignitor-rod and the ignitor-trip which snaps the ignitor-hammer at the right moment to make and break electrical contact between the electrodes inside the cylinder. The governor is of the centrifugal type, attached to the fly-wheel and designed so that when the speed passes a certain point the weights fly outward and operate on the exhaust valve rod, causing the exhaust valve to be held open. Air will

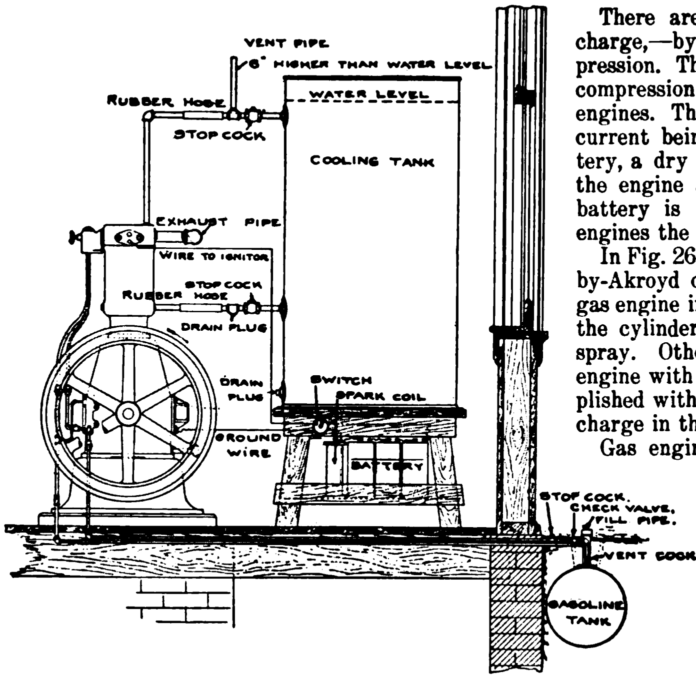


Fig. 262. Elevation of a vertical three horse-power four-cycle gasoline engine, showing connections with cooling tank and battery.

now be drawn into the cylinder through the exhaust port on the next stroke of the engine instead of through the inlet valve, and no fuel will be used, consequently the engine will miss an explosion. A small pump on the side of the engine pumps gasoline into the chamber C, from which it is fed into the mixing chamber through the needle valve; any surplus of gasoline returns to the tank by gravity.

The engine here described is fitted with what is called a hit-and-miss governor,—that is, when the speed rises beyond a predetermined point the governor causes the engine to miss one or more explosions, usually by holding the exhaust valve open. The constant intermittent application of power has a tendency to cause uneven speed, but this objectionable feature is overcome by using extremely heavy fly-wheels, which absorb a large part of the energy of the explosion and return it again during the stroke when no impulse is received by the piston. Gas engines built at the present time govern very closely and are as well-adapted for running delicate machinery in which uniform speed is essential, as are steam engines.

Another method of governing is applied in some engines, by which the air and fuel supply is throttled, thus limiting the force of the explosion to the work being done. These engines do not miss any explosions.

There are three distinct ways of igniting the charge,—by the electric spark, hot tube and compression. The hot tube is almost out of date, and compression is used very little except for oil engines. The electric method is far in the lead, the current being supplied by means of a liquid battery, a dry battery, or a small dynamo, run from the engine shaft. For stationary work the liquid battery is most largely used, and for portable engines the dry cell or dynamo.

In Fig. 263 is shown a sectional cut of the Hornsby-Akroyd oil engine. It differs from the ordinary gas engine in having a vaporizer on the head end of the cylinder into which the oil is pumped in a fine spray. Otherwise it resembles the ordinary gas engine with the igniter omitted. Ignition is accomplished with the heat generated in compressing the charge in the hot chamber.

Gas engines are rated usually at or very near their maximum capacity; that is, an engine that is rated as 20 horse-power cannot be made to develop more than that much power. Steam engines, on the contrary, are usually underrated; that is, an engine rated at 20 horse-power can be made to develop, in an emergency, as high as 30 or 40 horse-power. Because of this difference in rating, farmers have often been disappointed in substituting gas engines of the same rated horse-power as steam engines formerly used, to find themselves short of power. Gas engines which replace steam engines for farm work should be rated at least 50 per cent higher than the steam engines in order to do the same work. In other words, when a 20 horse-power steam engine was used, a 30 horse-power gasoline engine will be required.

A gasoline engine in first-class condition should develop one horse-power per hour with an expenditure of one-eighth to one-tenth gallon of gasoline. Kerosene and crude-oil engines have about the same record. The efficiency of the explosive engine as a heat machine is considerably higher than of a

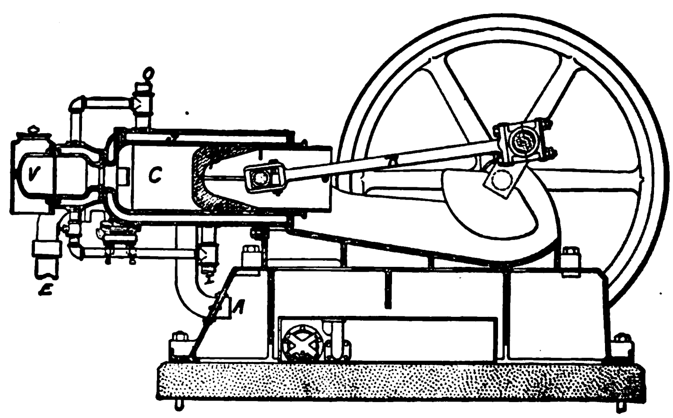


Fig. 263. The "Hornsby-Akroyd" oil engine, showing simplicity of construction. A, air pipe; C, cylinder; E, exhaust pipe; J, water jacket; R, connecting rod; I, water inlet; O, water outlet; P, piston; V, vaporizer.

steam engine. Ordinary gas engines show an efficiency of 18 to 20 per cent, while performances of 25 to 30 per cent for the larger-sized better grades of engines are recorded.

Alcohol motors are not yet used in the United States, owing to the high price of alcohol, caused by the internal revenue tax on all spirits. In Germany and France they are used extensively. In these countries, denatured alcohol, that is, alcohol containing some foreign substance, as benzine, to make it undrinkable, is placed on the free list, thus enabling manufacturers to place it on the market in competition with gasoline or kerosene. The alcohol industry in these countries also provides a market for a large part of the potato crop. As these pages go to press, Congress has passed an act removing the taxes from denatured alcohol; and a great development of portable power machines may now be expected in the United States. [Denatured alcohol will be discussed in Vol. II. See also page 214.]

Gas engines may be and are used for all purposes for which a steam engine is suitable; and for indoor work, and work in which only a small amount of power is required, they are superior to the steam engine. They take up less room, do not need a constant attendant, require very little water, and are available at a moment's notice. Besides, they are free from the danger of a boiler explosion. They are used very largely for pumping water, either for the farm buildings or for small irrigation tracts, for grinding feed, shelling corn, and running the small machinery about the farm; also, for threshing and in grain elevators. Almost all the grain elevators in the wheat-raising sections of America are equipped with gasoline engines of six to ten horse-power.

Gasoline traction engines have been put on the market within the past two years. They have been used for threshing and plowing and other work usually expected of a traction engine. The double-cylinder under-mounted pattern is one of the latest.

Another use for the gas engine which has recently been developed, and which promises to attain considerable proportions in the near future, is running a dynamo to furnish lights for farm buildings. A five horse-power engine is capable of running between 40 and 50 16-candle-power incandescent lamps, at a cost not to exceed three-fourths of a gallon of gasoline per hour. A large number of gasoline engine lighting equipments have been installed in large farm and country residences in the last few years, especially in the eastern part of the United States, and are said to give entire satisfaction.

Some idea of the magnitude of the gas engine industry may be gathered from the fact that 133 firms were reported in 1904 as building such engines expressly for the agricultural trade.

The hot-air engine.

The hot-air engine, also called the caloric engine, depends for its operation on the power developed by heated air without the intervention of steam or other gas to convert the heat into motion. The power depends on the pressure produced in heated air contained in a confined space. If the volume be kept constant, the pressure will increase in proportion to the absolute temperature. The absolute temperature is 460° F. more than the ordinary temperature.

The following explanation, together with the sectional drawing (Fig. 264), will give some idea of the working cycle of a hot-air engine. The compression piston, C, descends first and compresses cold air to about one-third of its normal volume in the lower part of the compression cylinder, A. The power piston, D, now starts upward, and the air is transferred by the completion of the stroke of the compression piston through the regenerator, H, into the heater, F, without appreciable change of volume. Here the air undergoes an increase of pressure due to the increase in temperature, which impels the power piston up to the end of its stroke. The pressure still remaining in the power cylinder reacts on the compression piston, C, and forces it upward till it reaches nearly to the top of its stroke, when by the cooling of the charge of air the pressure falls to its minimum. The power piston now descends and compression again begins.

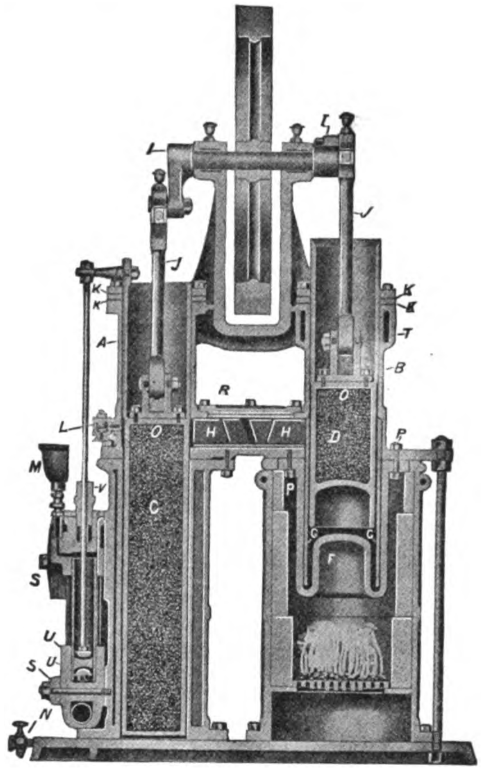


Fig. 264. Rider hot-air engine.—A, compression cylinder; B, power cylinder; C, compression piston; D, power piston; E, cooler; F, heater; G, telescope; H, regenerator; I, I, cranks; J, J, connecting rods; K, K, piston packings (leather); L, check valve, placed at back of compression cylinder, but shown at side on cut; M, pump primer; N, blow-off cock; O, O, knuckles; P, P, heater bolts; R, regenerator bonnet; S, S, pump-valve bonnet; T, water-jacket to protect packing from heat; U, U, pump buckets; V, pump gland.

The air, in the meantime, in passing through the regenerator, H, leaves the greater part of its heat in the regenerator plates, to be again picked up and utilized on the return of the air to the heater.

Hot-air engines are adapted for pumping purposes only, the motor and pump being inseparably connected. They are built only in small sizes and are capable of handling comparatively small quantities of water. They are plenty large enough, however, to supply the largest-sized stock-farms with water, or to irrigate forty or fifty acres of land. They possess certain advantages over either the steam or gas engine, such as simplicity of construction, ability to use any sort of fuel, ease of erection, and the need of no skilled attendant. They are made in sizes varying in capacity from 150 gallons per hour, with a fifty-foot lift, to 3,500 gallons per hour, and requiring an expenditure in fuel of two to ten pounds of coal, or one to six quarts of kerosene.

Hot-air engines are used extensively in country residences, on stock-farms and in various scattered

Fig. 265. Dutch windmill.

localities all over the United States. The larger sizes are used to a limited extent in pumping water for irrigation.

Windmills.

The windmill is a motor that transforms the kinetic energy of the wind into useful work. It consists of a wind-wheel placed usually on a high tower or the top of a building, connected to the machinery to be driven through a crank or gearing or proper shafting. The wind-wheel consists of a series of vanes or sails set at an angle and hung radially around the central axis. This axis may be vertical or horizontal. As a rule, it is horizontal or slightly inclined therefrom.

Windmills in one form or another have been used since very early times, but it was not until the twelfth century that they came into general use in Europe. They were used largely in Holland to drain the land by pumping water from behind the dikes into the sea. The first mills were stationary and were turned into the wind by hand. In the German mill the whole structure had to be turned, while in the Dutch mill, which finally became the standard mill of Europe, the head and wheel only were turned. Fig. 265 is an illustration of a typical Dutch mill.

American windmills may be divided into two classes: first, those that revolve in the same plane

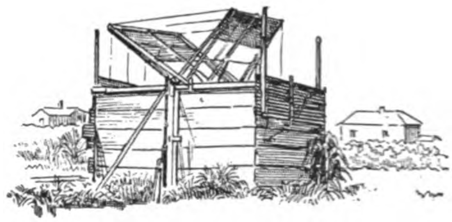


Fig. 266. Jumbo or paddle-wheel mill which rotates in the same plane as the wind.

as the wind, known as paddle-wheel mills; and second, those that revolve at right angles to the wind, known as turbine or sail-wheel mills. The mills of the first class are usually home-made affairs of the Jumbo type, illustrated in Fig. 266, of which large numbers are to be found in Kansas, Nebraska and some of the other western states. These mills are not very efficient, but have been found to be cheap and serviceable by a great many farmers. Ordinarily they have no means of regulation and must have half of the wheel screened from the wind, otherwise the wind pressures will be balanced and the wheel will not turn. These wheels are sometimes made with a vertical axis and are then known as "merry-go-rounds" (Fig. 267). In either the Jumbo or merry-go-round type, it is evident that the wind can work only on part of the wheel at any given instant, which accounts in part for their lack of efficiency. The horizontal paddle-wheels are usually set within a few feet of the ground and in the direction of the prevailing winds, which, in the western states, are from the north and south. They are of no use when the wind blows from any other direction, though efforts have been made to overcome this objection by building wheels with warped or screw-shaped vanes. In the case of vertical mills a revolving casing is sometimes provided, surrounding the wheel, which may be adjusted or

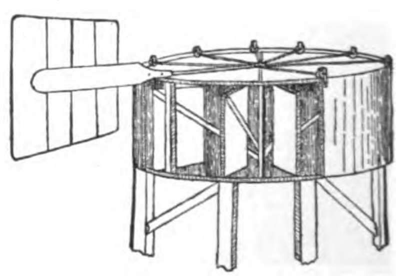


Fig. 267. The merry-go-round mill.

which will adjust itself to any direction of the wind.

The second, or sail-wheel type of mill, is the most common. A large number of home-made mills of this type are to be found in the West, and all shop-made mills are of this pattern (Figs. 268, 269).

In order to attain the highest efficiency, the wheel must be kept constantly in the wind and must be provided with some sort of governing device, that will insure a fairly constant speed in ordinary winds, a reduction of speed in high winds, and a complete stoppage of the wheel in a gale. In the Dutch mill the governing was accomplished

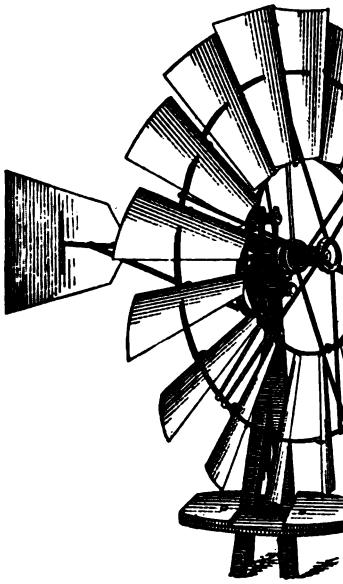


Fig. 268. A common solid wheel windmill. This type depends on a vane to hold the wheel in the wind and for correct regulation.

by an automatic device that reefed the sails in high winds; and in some of the more modern mills a small auxiliary wind-wheel was used to keep the wheel in the wind. But the unwieldy size, slow speed and high cost of these mills, and the fact that they were not designed in such a way as to be profitably manufactured in large numbers, prevented their being generally used in the United States. It was not until an American mill was invented that the windmill came into general use in this country.

The American type of self-regulating windmill came into existence some time between the years 1857 and 1867. The development of the modern windmill dates from that time. Between these two dates, two types of windmill were invented, the sectional wheel by Mr. Daniel Halliday (Fig. 269), and the solid wheel by the Rev. Mr. L. H. Wheeler (Fig. 268). All wheels at the present time are built in one or the other of these two styles or some modification of them. Some mills of the first type are provided with a vane or rudder to hold them in the wind, and some are vaneless. Those of the second type depend on a vane or a small auxiliary wheel to hold them in the wind and for correct regulation.

The sectional wheel-mill is governed by the centrifugal action of the sections, whose inner ends tend to project out toward the wind when the speed increases, thus reducing the effective sail area. This tendency of the sections is counterbalanced by springs or a weighted lever, which also pull the sections back into the wind when the speed decreases (Figs. 269, 270).

The solid wheel generally depends on wind pressure for its governing principle instead of on centrifugal force. The axis of the wheel is set a little to one side of the axis of the head, and is held in the wind by a vane or rudder, which is hinged to the head and is held in position by springs or weighted levers (Fig. 268). When the wind pressure becomes too strong, or stronger than the governor is adjusted for, it pushes the wheel round parallel with the vane, at the same time overcoming the effect of the springs or weights as it turns the wheel out of the wind. When the wind pressure decreases, the springs or weights force the wheel into the wind again. Another method of governing sometimes applied in the solid wheel is a centrifugal governor, which changes the angle at which the sails are set in accordance with the speed of the wheel; in other words, no matter how strong the wind, the wheel cannot exceed a certain speed (Figs. 271, 272).

Windmills may also be classified as pumping mills and power mills. Pumping mills are direct stroke mills; that is, the crank is fastened directly to the wheel-shaft and makes as many turns as the wheel does. Power mills are geared, that is, a set of gearing connects the wheel with the main vertical shaft, which has a motion either faster or slower than the wind-wheel, depending on the ratio of the gearing and the kind of work for which it is designed. The vertical shaft in power mills is made to revolve instead of being worked up and down, as in the case of the direct stroke mill. Mills of this class may be used for pumping by using a pump-jack, and are suitable for any power work within their range.

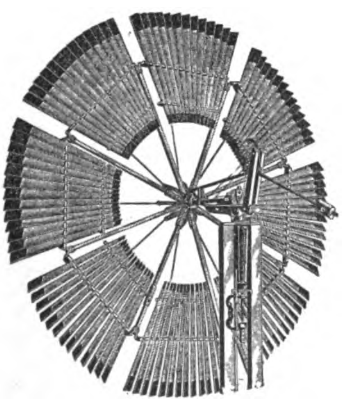


Fig. 269. Twelve-foot sectional vaneless pumping mill. In the wind.

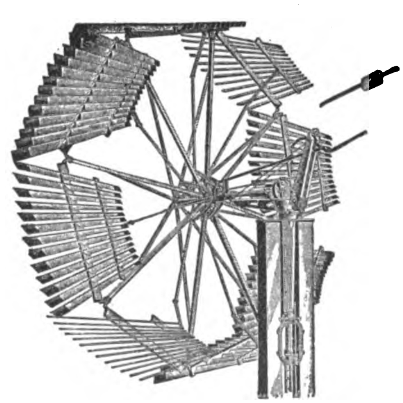


Fig. 270. Fourteen-foot sectional vaneless pumping mill. Out of the wind.

The principal use made of windmills in America has been, and is yet, in pumping water for stock and for farm buildings. With the advent of heavy, steel power mills in the past few years, they are finding considerable use in grinding and cutting feed, sawing wood, running the grindstone and other small machinery used in the farm workshop. They are also used largely in pumping water for irrigation purposes in various parts of the West, especially in the San Joaquin valley, California, and

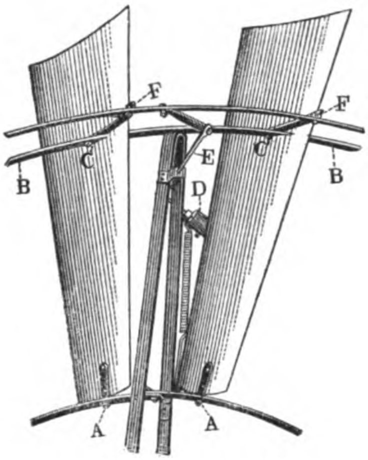


Fig. 271. A centrifugal governor. Position in a light wind.

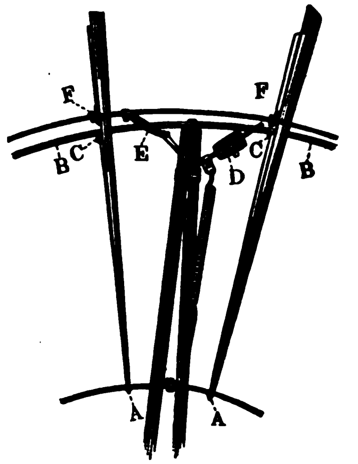


Fig. 272. A centrifugal governor. Position in a high wind.

near Garden City, Kansas. One 16-foot mill is capable of irrigating one to five acres of land. Owing to the uncertainty of the wind, a storage reservoir is necessary for an irrigation plant. The initial cost of windmill irrigation is estimated at \$15 to \$20 per acre, and the cost of maintenance is practically nothing. Numerous experiments have been tried to adapt windmills to the running of a dynamo to be used in connection with a storage battery, and thus furnish power and light for farm use. Some plants of this kind have actually been installed, but they are expensive, the wind is very uncertain, and it cannot be said that the experiments have been entirely successful.

The power developed by windmills is comparatively small. According to Thomas O. Perry, a 12-foot mill in a five-mile wind will develop one-fortieth of a horse-power, in a ten-mile wind, .2, in a twenty-mile wind, 1.6 and in a thirty-mile wind, 5.4 horse-power. Professor E. C. Murphy states the actual performance of a 12-foot wheel as one horse-power in a twenty-mile wind, and 1.4 horse-power in a twenty-five-mile wind; while a 16-foot mill develops 1.5 horse-power in a twenty-mile wind and 2.3 horse-power in a twenty-five-mile wind.

A 12-foot wheel with 50-foot tower weighs about 2,000 pounds, while a 16-foot mill with 50-foot tower weighs about 4,250 pounds, develops one and a half times as much power and costs twice as much. It would appear to be better economy, at least in pumping, to use a number of small-sized wheels, say 12 feet in diameter, than one large one. More power can be obtained for the same money expended and with less liability of the mills being damaged during storms. In general, the higher the tower the more power obtained. In any event, the tower should be higher than surrounding buildings and trees by at least 15 feet.

Professor Murphy is authority for the following windmill principles:

1. The speed of the wheel for a constant load varies as the square of the wind velocity.
2. The speed of the wheel for a maximum load increases slightly faster than the first power of the wind velocity.
3. The power of the mill for a constant load varies as the square root of the wind velocity.
4. The maximum power of the mill varies as the square of the wind velocity.
5. The load for maximum power does not increase so fast as the wind velocity.
6. The ratio of speed for maximum load to the speed for no load increases somewhat with the wind velocity.
7. The power of a windmill increases as the 1.25 power of the diameter of the wind-wheel.

The last item shows that increasing the diameter of the wind-wheel only slightly increases the power of the mill and justifies the foregoing statement that several small wheels are preferable to one large wheel.

Water motors.

The various kinds of water motors may be thrown into two classes, water-wheels and water-engines. Among the former may be mentioned undershot wheels, breast wheels, overshot wheels, hurdy-gurdies, Pelton wheels and turbines. As generally understood, the term water-wheel applies only to the older forms of wheels such as the first four just mentioned. Among the latter class there are bucket engines, rams, and water-pressure engines.

Water motors are not employed directly in agriculture to so great an extent as the steam engine, internal-combustion engine or windmill, owing to the fact that comparatively few farms are favorably located for their use. Indirectly they have been, and are yet, used considerably for such work as running flour mills and pumping water for irrigation. More recently they are finding some application in furnishing electrical energy which is utilized by the farms along the line of power wires. A notable example of the use of this hydro-electric power is found along the Pacific coast, where the power from the high falls of the Sierras is converted into electrical energy by means of impulse wheels developing enormous power. This hydro-electric power is cheap and very efficient in creameries and on the farms for driving threshing-machines, pumping water, cutting feed and like work.

When a stream within high banks cuts across a farm, a dam may be thrown across and a water-wheel installed which will furnish a cheap efficient power for lighting the farm buildings and driving much of the machinery. If the power of the stream is large enough, several farmers may club together and install a water-wheel and dynamo, and thus make the power available for a mile or more from the power plant. By means of motors, this power can be utilized to drive whatever machinery it is found desirable to connect with.

Even a stream within low banks may be utilized for power if there is opportunity for a long overflow below the dam, thus allowing for the making of a flume or race at a place where the head is sufficient (Fig. 273).

Undershot water-wheels (Fig. 274) are used considerably in irrigation work throughout the West, especially the type known as the mid-stream wheel. This type of wheel is set so that the lower paddles dip into the water, and is arranged either on pontoons or on movable bearings so as to be adjustable to the varying height of the stream. The motive power is due to the velocity of the stream in which the wheel is set. When water is abundant and the lift is not greater than the diameter of the wheel, these wheels may be employed advantageously for irrigation. They are cheap and very simple in operation. When fitted up for this kind of work they are commonly home-made and fitted with buckets attached to the paddles, which fill with water when they are submerged and spill their contents into a conduit when at or near their highest elevation. Wheels of this type have been used for ages in Egypt, Italy and in other parts of the world, and are commonly called norias. Numerous wheels of this class are in use in various parts of the West. Fig. 275 illustrates a wheel of this kind at Fresno, Cal., that raises water twelve feet and irrigates twelve acres of orange and shade trees. On the Green river in Colorado there are some wheels twenty or thirty feet in diameter, hung on heavy wooden axles, pumping as much as 4,000 cubic feet of water per day. In some cases, undershot wheels are connected by means of suitable gearing or belting to pumps that elevate the water to a considerable height. An example of this arrangement may be found on the Platte river, where a 3½-inch centrifugal pump elevates five acre-feet of water every twenty-four hours to a height of sixteen feet.

Fig. 273. The development of water power on a New York farm, by damming a small brook. The mill or shop is at E. The pond is at A, providing a head of 16 feet. The creek follows the line C; the other line, S, is a road. The mill is run by a 25-horse-power turbine. In the shop light sawing is done; and there are cider-press, bone-grinder, grindstone, feed-mill, and other power machines. A 7-horse-power wheel fed from the same flume runs a dynamo that supplies electric light for dwelling, yard and barns.

Overshot wheels (Fig. 274) use less water than current wheels and are, therefore, employed when water is scarce. In wheels of this class, water is delivered by means of a flume on either the far or near side of the wheel, depending on the arrangement of the outlet gates controlling the supply. On the outer rim of these wheels a series of buckets is constructed into which the water pours and by its weight causes the wheel to revolve. The buckets fill as they pass the inlet orifice and empty as they approach the bottom: thus one side of the wheel is always loaded, while the remainder of the buckets are empty. This type of wheel may be used on falls of 6 to 60 feet, and is suitable for running pumps, dynamos or any other machinery within reach.

Breast wheels (Fig. 274) take the water at about midway of the height of the wheel, and depend for their motive power partly on the impulse of the water and partly on its weight. The flume for a wheel of this class should be carefully made to prevent loss of water. These wheels have been used to some extent to drive flour mills, but so far as known have not been otherwise employed in agriculture.

Turbines.—There are several types of turbines on the market built by manufacturers of hydraulic supplies. Wheels of this class have a much higher efficiency than any of the older types of wheels, and are suitable for falls of 10 to 300 feet. For high falls a comparatively small wheel will develop a great amount of power. These wheels are used for driving heavy machinery, such as flour mills, electric power plants and the like. They are also used to pump water for irrigation, a notable example of this use being found at Prosser, Wash., where a turbine power and pumping plant has been erected capable of irrigating 4,000 acres of land.

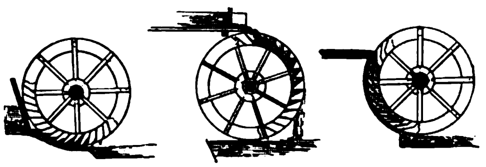


Fig. 274. Kinds of water-wheels,—undershot, overshot, breast.

Cup wheels.—For the extremely high falls found along the Sierra mountains in California, a form of impulse wheel, shown in Fig. 276, is used. These wheels have been employed on falls as high as 2,000 feet and yield an efficiency, it has been stated, as high as 90 per cent. For these extremely high heads they are said to be the best type of wheel to use. They find their application to agriculture in an indirect way, as indicated in the beginning of this article.

Bucket engines are an obsolete form of motor which performed work by allowing water to enter the buckets, causing them to descend vertically.

Rams.

When a large spring issues from a side-hill, or a stream has a good fall, an hydraulic ram may be installed to furnish the farm buildings with water, or even to irrigate small tracts of

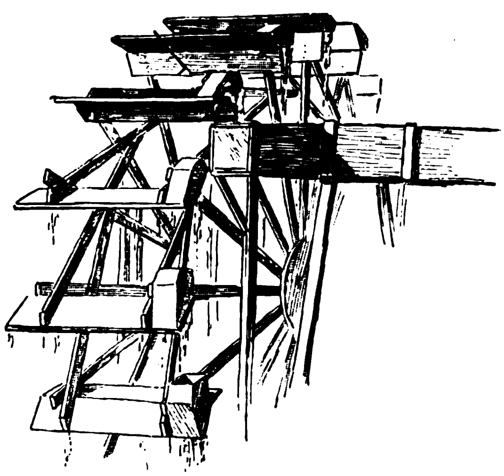


Fig. 275. Special form of undershot water-wheel used for raising irrigation water in California. The buckets on the side of the wheel empty into the trough.

land. When such a motor can be used it is sometimes a very effective pumping-engine. It is cheap, easy to keep in running order, and simple in construction. It works on the principle of utilizing a large volume of water, falling a comparatively short distance, to force a small quantity of water to a great height. The performance of rams is about as follows: One-seventh of the supply-water can be elevated to five times the height of the fall; or one-fourteenth part may be elevated ten times the height of the fall; or one-twenty-eighth part, sixteen times the height of the fall. The efficiency decreases with the height of the fall, but for comparatively low falls may run from 60 to 70 per cent. Rams provided with a snifting valve that maintains an air supply in the air-chamber, are best adapted for the higher falls. In general, the height of the fall should be two to ten feet, but many rams are operating with a much higher fall. In installing a ram, care must be taken that the pipes be protected from frost. The supply-pipe should be about 75 per cent as long as the delivery-pipe and its diameter three to four times that of the delivery-

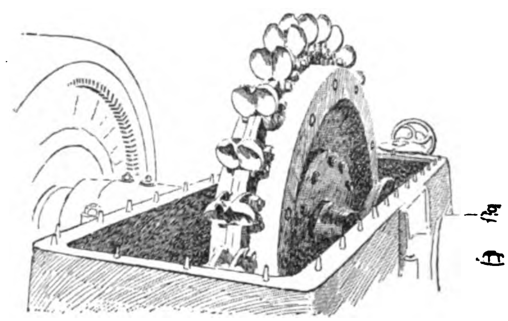


Fig. 276. Type of impulse water-wheel, used for very high falls.

pipe. There are many styles of rams on the market, and care must be exercised in selecting the one most suitable for the location in which it is to be installed. [For further discussion of rams, see Chapter VIII.]

Water-pressure engines operate in somewhat the same way as a steam-engine, producing reciprocating motion because of the pressure of water confined in an upright pipe. They are not used in agriculture, except perhaps in a very few localities for irrigation.

The power of a stream may be calculated by the following formula: $P = Awh$, in which A is the number of cubic feet of water falling in one second of time, w is the weight of a cubic foot of water, and h is the head or height through which the water falls. To reduce this to horse-power the formula should read: $H.P. = \frac{Awhe}{550}$, in which *e* represents the efficiency, in percentage, of the type of wheel to be used. The efficiencies of the various types of water-motors run about as follows:

Undershot water-wheels	35 per cent
Poncelet wheels	60 " "
Breast wheels	55 " "
High breast wheels	60 " "
Overshot wheels	68 " "
Pelton wheels	75 " "
Turbines	60–80 " "
Water-pressure engines	80 " "
Rams	60 " "

These values are only approximate and may vary either way several per cent, according to the method of installation, quality of the machinery, and other factors.

Electric motors.

Electric motors are used very little at the present time for running farm machinery in this country. Since the electric motor requires a dynamo to supply a current, and the dynamo depends on some engine for its operation, the complete outfit becomes rather too expensive and too complicated for the average farmer. However, in some favored localities near a power station, or along the line of an electric railway, where electric power can be bought from the power company, or when a number of farmers are so situated that they are able to install a coöperative power and lighting plant, the use of electricity for running machinery will be found to be very satisfactory. Under these conditions it is cheap and offers certain advantages not secured by the use of any other motor. It is clean, safe, takes up small space, and is instantly available. An electric motor can be used anywhere on the farm by extending the power wires. Several manufacturing firms have begun recently to build electric equipment for farm work, and there is good reason to hope that the near future will see a large growth of the electric industry in this field. Electric power is used to a considerable extent on the large farms in Germany for threshing and other indoor work, and to a limited extent for plowing.

The following literature may be consulted for further information on farm motors:

Animal motors—The Animal as a Machine and a Prime Mover, by R. H. Thurston; Physics of Agriculture, by Professor King; Animal Metabolism, by Professor Atwater. Steam engines—Twelfth United States Census; files of American Thresherman; files of The Thresherman's Review; Manual of the Steam Engine, by R. H. Thurston. Internal-combustion engines—Works of the German Agricultural Society, Vol. 78; Twelfth United States Census; The Practical Gas Engineer, by E. W. Longenecker; The Gas Engine, by Professor Hutton; files of The Engineer; files of Farm Implement News. Windmills—Water-supply and Irrigation Papers, Nos. 20, 41 and 42, United States Geological Survey; University of Wisconsin Agricultural Experiment Station Bulletins, Nos. 68, 82; University of Nebraska Agricultural Experiment Station Bulletin No. 59; The Windmill as a Prime Mover, by Woolf. Hot-air engines—Thermodynamics, Peabody; Irrigation Engineering, Wilson; Life of Ericsson, Cyclopedia of Applied Mechanics, Appleton. Water motors—Hydraulic Motors, Turbines and Pressure Engines, G. R. Bodmer; Water or Hydraulic Motors, P. R. Björling; Water Power, Frizell; Scientific American, Aug. 20, 1904, Vol. 58, No. 1494.

CHAPTER VII

FARM BUILDINGS AND FENCES

EVERY BUILDING ON A FARM should be adapted directly to its uses; yet most farm buildings are traditional in plan and largely even in construction. The methods and even the ideals of farming have changed greatly and have become crystallized in new machinery, new crops, new organization and new means of finding markets; these changing ideals will work an evolution in buildings, for the buildings become an expression of the farm. The old buildings express a former order; however well-adapted they may have been to that order, for the most part they are hopelessly inefficient for the new order, and therefore also hopelessly inartistic. Nothing is more needed on American farms than new kinds of buildings, constructed on correct fundamental ideals.

The three great classes of purposes to be considered in the plan of any building are these: (1) to accomplish the particular end for which it needs to be built; (2) to provide for the economizing of labor, time and effort in the accomplishing of these ends; (3) to afford sanitary conditions for man and beast. Most old farm buildings, either residences or barns, fail to meet these great requirements. In construction, they should be well made, able to stand as long as needed, and satisfying to a sensitive taste. The keynote of a good building is efficiency; and if it is completely efficient it is usually artistic in the best sense.

Not only the buildings themselves, but the disposition and arrangement of them have relation to their efficiency and tastefulness. It is unquestionably true that there has been a tendency to scatter the buildings, particularly the barns, far beyond the point of efficiency and convenience. It would be interesting to make a computation as to how much time and labor are wasted each year in doing chores in separated buildings. It would seem that good executive management would try to concentrate one's activities. Often the hay is in one barn, the horses in another, the cows in another, the wagons in another, and the corn in an isolated crib. No doubt it would be cheaper to build many of these departments together as compartments in a single structure; or, if these departments arise after the main barn is built, it is often possible to join some of them to the main structure rather than to make wholly separate units. The cost of maintenance of buildings is increased with several small separate structures; and the lack of organization of time and effort entails a still greater loss. The mere protection from the weather in doing chores is no inconsiderable advantage of a centralized layout, particularly in a rigorous climate. Compare Figs. 151 and 160. To a lesser degree, these remarks will also apply even to buildings in the South. An argument against the consolidation of the departments is the greater likelihood that fire may destroy the entire plant; but, as a matter of fact, it is difficult to save the separate buildings as they are usually placed. Moreover, the buildings are generally protected by insurance, and one can carry a relatively larger protection on one good building than on several poor ones; and the chance of fire is probably less in the one building than in several. A good building also should have means of fire protection.

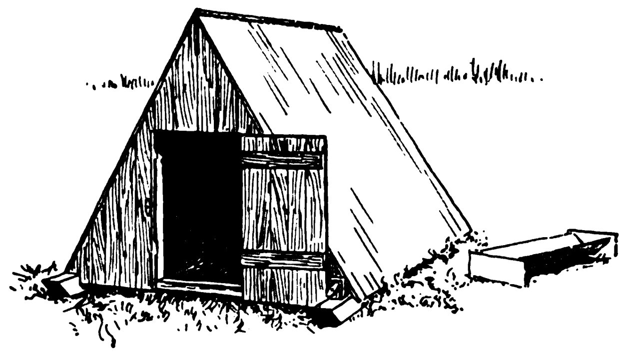


Fig. 277. An example of good architecture — simple, of good proportions and directly adapted to its purpose. Individual hoghouse on skids.

Buildings should be efficient in themselves,—so planned as to save steps (or be "handy"), and also to separate unrelated work. The modern farmhouse, even though small, should contain some provision for a laundry; and, when there is a motor about the place, it can be used for effective laundry machinery, for perhaps no farm work is more ineffectively and laboriously performed than the washing. All farm dwellings and stock-barns should be provided with running water.

Fig. 278. A study in proportions. All these structures are of the same capacity and the doors are of the same size, but the buildings differ greatly in tastefulness.

"Dust-lines" must be eliminated. Many weary hours of hard work will be saved and much will be gained in sanitation when meaningless mouldings and panel-work are forever discarded. It is difficult to conceive of any reason for building projecting door-cases and window-cases on the walls except to cover poor plaster work and poor joints (corners can be protected by other means, if necessary); and yet the trouble is often increased by nailing mouldings on the casings. The use of metal lath will allow us to round the corners, making a neater, stronger, more lasting and more sanitary finish, obliterating places for the collecting of dust. Fig. 292 contrasts the ugly and cumbersome old style with the neat and simple new style. Carpenters will object to building a house without the heavy casings, the picture mouldings, the panel doors, the projecting mop-boards, and all the other crack-making and dust-collecting constructions; but the new order must come. If made of good material, a perfectly plain, smooth, neatly polished door devoid of panels is handsomer than one of panel-work and bead-work, and easier to keep clean.

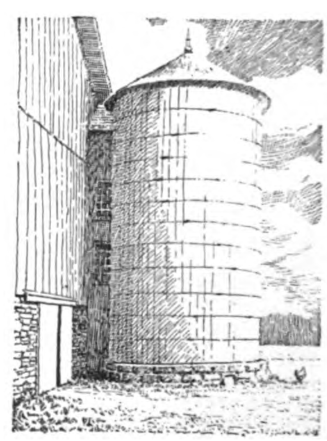


Fig. 279. An architectural form that is inharmonious with the building, but which is acceptable because necessary. If this were a mere turret or tower, it would be inadmissible on a barn.

Taste in farm buildings.

The element of good taste is fundamentally important in the construction of any building; but in farm buildings it assumes special importance because the buildings stand alone and are prominently conspicuous.

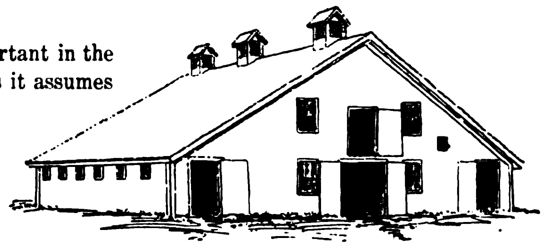


Fig. 280. Simple and strong lines. If this barn is exactly adapted to its purpose, it is good architecture.

We are all strongly influenced by every constant condition of our lives. All of us live in buildings, and from the first to the last we associate with them. These buildings are silent teachers, always impressing us more deeply than we are aware. Sense of convenience and efficiency, of pleasing proportions, of tasteful shapes and harmonious colors ought to be the lessons that our buildings impress on us; yet how many farm buildings are really convenient and efficient, or of good proportion, or express harmony of form and color?

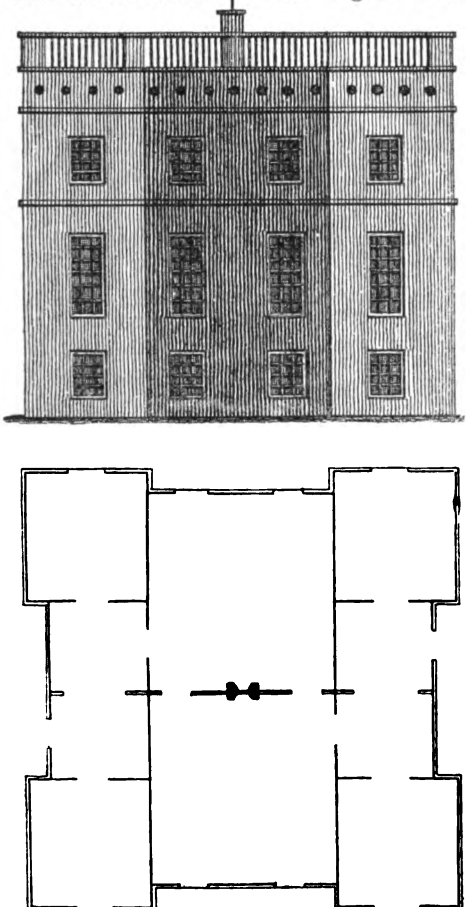


Fig. 281. "Plan and Elevation of a country habitation," as proposed by J. B. Bordley in 1799 (Essays and Notes on Husbandry, Philadelphia), one of the very early plans for a farmhouse, and now one of the curiosities of agricultural literature. "The annexed drawing of a plan and elevation," Bordley says, "may afford hints to persons who would build in the country. It is not the intention to give a design to be particularly followed; but *principles* only, on which others may build to suit themselves. The principles on which this plan is formed afford many conveniences and much room; little being wasted in useless applications of the area, which divides, in various ways, very advantageously. The middle rooms must be very comfortable in summer, from being defended on the E. and W. sides from the sun shining on and heating the walls, and being aired by opening the S. and N. windows, and the partition doors occasionally."

It may be difficult to determine what is cause and what is effect—whether poor taste is the result of poor buildings or poor buildings the result of poor taste; but the influence undoubtedly works both ways. The buildings surely express the man,—we know something of his type of mind when we see his house and barns and sheds. Awkward, straggling, unrelated buildings indicate loose and purposeless ways of thinking. Good farming follows only good mental processes: these processes work themselves out in the crop-schemes, the market-business, the buildings. Rarely do we see efficient and convenient buildings without seeing also a good farmer; and efficient and convenient buildings, as already said, are almost necessarily tasteful buildings.

There is no abstract canon of good taste in farm buildings except that they shall be perfectly adapted to the uses for which they are designed and shall bear no meaningless or irrelevant parts or ornament. Theoretically, the cylindrical stave silo is inharmonious in connection with farm barns; but because it serves a direct purpose, we accept it without question. (Fig. 279.) If such a construction were added merely "for looks," it would be ridiculous. The surroundings—the trees, bushes, yards—may correct many of the faults of untasteful buildings by hiding the faults, or by distracting the attention; but every building should be attractive in itself.

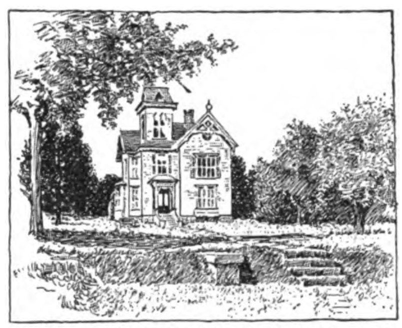


Fig. 282. A city type of house that may be out of place on a farm, and therefore inartistic there.

It should be as easy to make a building attractive as to make it unattractive: it costs no more. What many persons think of as "architecture" is merely the "style" or "looks" of a building. Unfortunately, we seem to have it indelibly written into our minds that attractiveness is only a matter of ornament; but ornament is ludicrous on an ugly building. We must come to realize first of all that every building is good architecture or poor architecture, whether it is a chicken coop or a palace. Good architecture, so far as externals are concerned, consists primarily in proportions, not in trimmings, excrescences, ornaments and oddities. What constitutes good proportion may not be declared off-hand, for what is good proportion for one kind of building may be poor proportion for another kind of building. Every man can test the question for himself, and he will soon become expert at it: let him challenge every building that he sees and ask whether it is pleasing in general shape. Is it compact and solid-looking, or awkward and gawky?

Fig. 283. Good lines in a corn-crib.

Perhaps the commonest faults with farmhouses are that they are high, staring, ill-shaped. Farmhouses are mentioned advisedly, for farm barns are usually much better in architectural form, and for the simple reason that no effort is expended to make them "handsome" or unusual—they are built for what they are and with no pretensions. Most of the old-fashioned farm buildings are pleasing in form, although they may be wholly lacking in convenience of plan. They are relatively broad on the ground, with ample cornices and eaves, stout chimneys, and big, simple porch posts. They seem to belong to the place. They look like real farm structures.

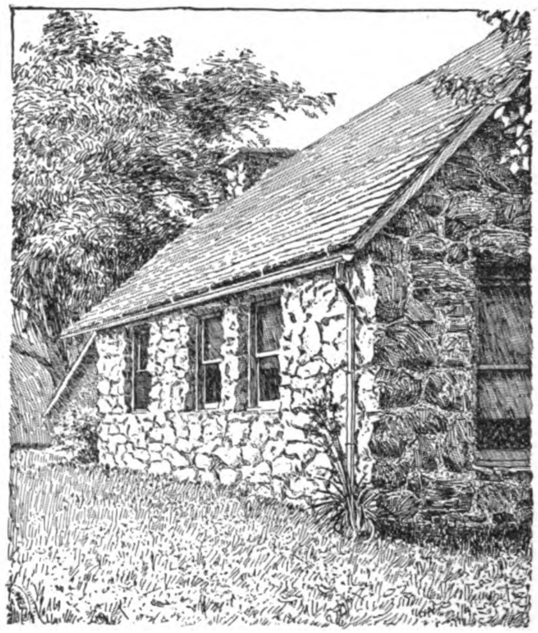


Fig. 285. Rough and good stone work, such as should be much commoner in farm buildings. A farm cottage in central New York.

Now we have copied the millinery architecture of the city. We have run our buildings up where they may be seen, and as if land were worth so much the square foot; and often we have loaded them with tatting. The porch posts have been run through the turning lathe until they are as slender as possible and yet hold the load, thus contradicting the very purposes for which posts are used—the purpose to provide stability and solidity. The turner shows his skill by cutting them almost in two in several places, and by shaping out various inharmonious forms on the same post. It is impossible that a cylindrical or square pillar of good proportions is made more beautiful or useful by having quirks and undulations run into it, although it may sometimes serve very well as one element in a scheme of ornament. The spindle-legged porch usually goes with a light-construction and weak-looking house. The reaction of the town on the country in the matter of architecture is stronger than most persons are aware. One rarely sees a new farmhouse adopting the old farmhouse models. Part of the reaction expresses itself in the desire of every person to have a house unlike every other person's. This is really commendable, only that this individuality should be secured by a different fundamental plan rather than by the introducing of mere oddities or accessories. Persons now are likely to feel that buildings must have what is called "style,"

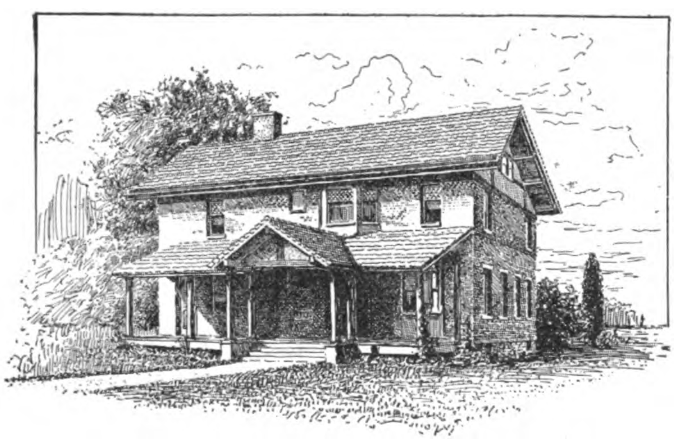


Fig. 284. A house of simple and strong lines, well-suited to the country. See Fig. 297.

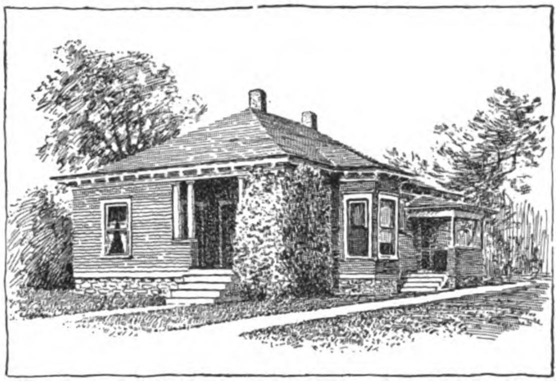


Fig. 287. A compact square house of the western type.

and this results in a showy building with much effort expended on incidental parts,—scroll work, crests on the ridge, turrets, dormers, fantastic windows, spindle work, and the like. If any house should look to be strong and substantial, it should be the farmhouse. The farmhouse stands by itself. It is not built to sell, nor to serve a single generation. Land is substantial: the buildings go with the land.

It must not be understood that the country is worse than the city in respect of its buildings. In fact, the country is better off because its buildings are less ambitious and showy. It is difficult to conceive of a prospect more ugly than many village or city streets, with their heterogeneous and formless houses. It is time to set farm people thinking about the "looks" of their buildings, and to say that there is as much opportunity for the exercise of good taste and for the display of good "architecture" in simple farm buildings as in city buildings.

It is not meant to advise the discarding of all ornament on buildings; but there is ornament of proper kind and degree and of improper kind and degree: just what is proper or improper in any case must be determined for that case alone. A building devoid of all conspicuous ornament may be very attractive, if the general form is good and the openings properly proportioned to each other. The cheap ornament that is so commonly seen is added to relieve the "plainness" of the building; but plain buildings—that is, simple and direct ones—are themselves the most satisfying buildings if the mass-effect and construction are good. Let a person erect such a plain building in the midst of showy ones, and his friends will very likely compare it to a barn. The comparison may really be a compliment; in time the critics will come to like the simple structure and to tire of the others. The simple structure "wears."

Fig. 286. The upright and wing of the old style.

In the days of hand-work, the trimmings and ornamental features were worked out by the men who built the house, and there was likely to be harmony in the style of workmanship. Now, the ornamental features are largely machine work, and they may have little relation to the remainder of the building. For these reasons, we need to exercise great care in the treatment of the "finishings" of a building.

Because a building is in keeping in the city, it does not follow that it will be in keeping in the country. The building should fit the place and the purpose. It should seem to belong just where it stands. It should not seem to be transplanted to the country. The traveler often wonders why the simple and unpretentious peasant cottages in Europe are so interesting. The reason is just because they are simple and unpretentious, and therefore individual. They seem to have grown up out of the land

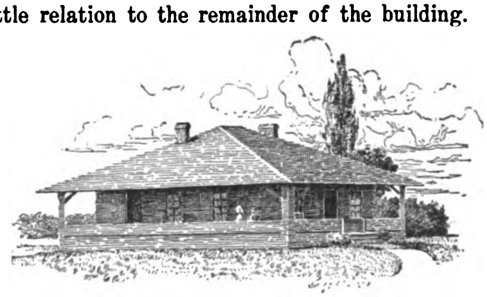


Fig. 288. A square-roofed porch-surrounded California farmhouse.

and to be a product of it, expressing merely the necessities of the builder. They were built slowly right where they stand, not carted in bodily from the mill and then set up. It is too bad that in those parts of North America where rock and stones abound, there are not more stone buildings. Unfortunately, stone buildings are expensive because of the great cost of masons' wages and the difficulty of securing masons in the country who can lay a good rough, untrimmed wall (Fig. 285); yet we ought to be developing a class of young farmers who themselves can utilize the native materials of their region.

Fig. 289. A direct and useful house in the windy country of the plains.

Certain types of buildings are peculiar to great geographical regions or to people of a certain descent. In parts of New England one sees the house, woodshed and barn comprising one continuous building (Figs. 29, 31, 160, pages 36, 38, 149). In most of the older parts of the country, a prevailing type is the "upright and wing" form. In compact villages and cities this form of house has been given up. It is a question whether it affords the most useful and convenient house for a farm or allows the most economical use of the materials. It lacks compactness; but it lends itself well to the parlor and the spare-room idea, for these apartments can all be placed in the upright and be out of the way. The family usually lives in the wing. One could write an essay on the type of mind in our ancestors that developed this particular form of house, relegating the family to one sphere and the company to another sphere. Another interesting discursive type is the "ell," which ambles off to one side. In marked contrast to all this, one finds beyond the Missouri, and especially in California, the compact low-topped house, in which practically all the activities are under one roof. (Figs. 287, 288.) These houses may grow large by extensions rather than by wings, all the parts being under roofs of equal height. These buildings are often models of concreteness and concentration, and usually they are comely. It is a wonder that some one has not adapted them to the East. In the South, the buildings are constructed for "air," with large rooms, high ceilings (lower ceilings with good ventilation might be better), abundant porches, and often with no underpinning.

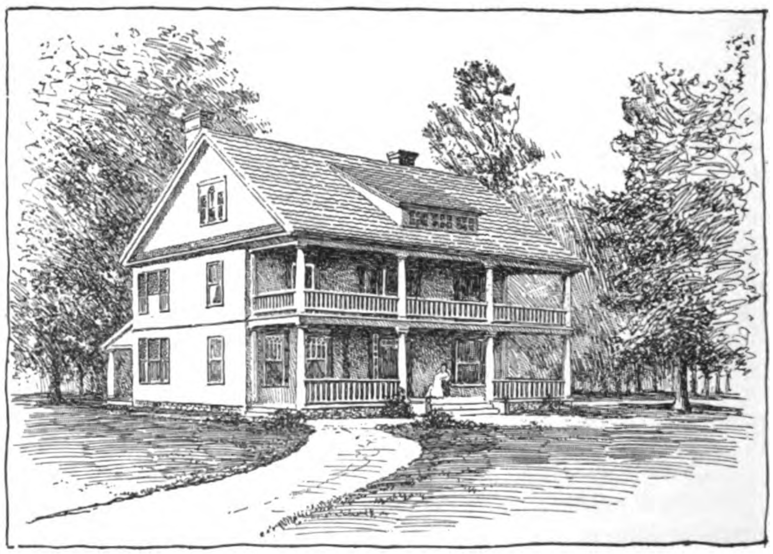


Fig. 290. An attractive farmhouse in Ohio. (Residence of J. E. Wing.) See Figs. 295, 296.

The old-fashioned box-corniced farmhouses are faulty in the small extent of veranda—commonly they had only a "stoop"—and also in the lowness of the upper story. Many of the newer houses have gained in high roomy chambers, but are likely to have lost in width and in too high and narrow gables. These old buildings were painted white. The Editor will not commit himself on the proper color for a farmhouse; but the range of colors in mixed paints affords boundless opportunity for the display of "tastes." The question may be raised whether the pleasing effect of the white on the old buildings is not in part the simplicity and plainness and the fact that one cannot make disharmonies.

The remedies.

It is conceivable that the reader may agree with nearly all that has been said; yet he will ask what good it serves, since the farm buildings in most parts of the country are now all built. Some new farmsteads are being erected, however, either on wholly new sites or to replace old buildings, and practically all the present structures must be replaced within a generation or two. Yet the case is not hopeless even with existing buildings. Additions are made to old buildings, and too often these additions contradict the spirit of the older part. In driving through any country, one may amuse himself in observing how many buildings show glaring evidence of having been "added to." Sometimes one can correct minor faults by judicious repairing or inexpensive modification. Often a too slender chimney can be broadened above the roof-line. Jig-saw skirting can be sawed off or neatly boarded over. Spindly porch posts can be boxed in and made square. Weak or unsightly foundations can be covered or screened by grading or by planting. Always, the building can be left in a neat and completed condition. It is not uncommon to see scaffolding remaining for years, particularly on silos (Fig. 291), and lumber and other material lying loose and exposed. Even if one cannot afford to complete a structure at once, there is a knack of making things look ship-shape. The farmer, as well as the mechanic, should have a pride of workmanship. If our buildings express ourselves, it is essential that we give careful attention to ourselves as well as to the buildings; and if buildings are teachers, it is important what kind of appeal they make to children and to strangers.

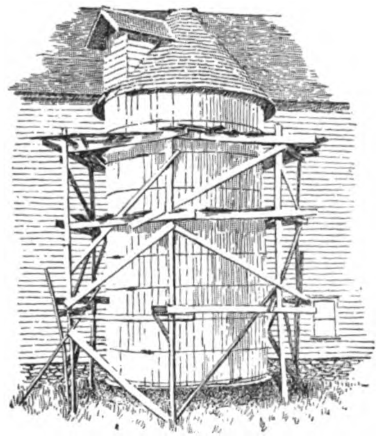


Fig. 291. Scaffold remaining long after the silo is completed, evidencing lack of appreciation of tidiness and good looks.

The responsibility of reorganizing farm building must lie very largely with the colleges of agriculture, since the fees will not be adequate to attract the services of professional architects. The architect's work thus far devoted to farm buildings is nearly all applicable only to structures designed for country homes or for very special kinds of agriculture. Moreover, many of the problems involved in these buildings are distinctly agricultural, as in the construction of creameries and buildings for dairy cows, poultry, swine. The improvement of farm buildings must be largely an accompaniment of the educational movement, inextricably associated with the general betterment of agriculture. The movement must also extend to all buildings in the country, whether on farms or devoted to schools, church work, or to public gatherings. It will be a happy day when the central four corners in every large rural community shall bear four buildings,—school, church, library and museum, general assembly hall. In particular, the rural school-building is now sadly in need of attention. The new school, effective for the life of its community, cannot come in the present single-room unadapted school-building. Every school-building must contain a room in which the pupils may "do things," may work with tools, and may keep and handle the natural objects of the region. The building must be well ventilated, well heated, well lighted, sanitary, attractive. All this means that new buildings must be made. The country church buildings are perhaps as much in need of reorganization as the schoolhouses. They are now largely cold, stiff and forbidding in appearance. The new church will contain much more than a preaching room and a vestibule.

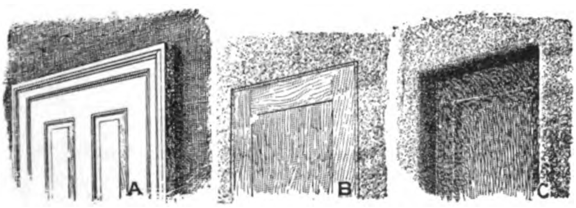


Fig. 292. The old and the new in door finish. A shows the heavy and useless dust-collecting casings and panels now in use. B and C show the two sides of tight, tidy and simple doors, none of the work projecting beyond the walls.

It is not too much to hope that a century hence will see a new kind of structure and construction in the open country.

Books and periodicals on farm buildings, recommended by correspondents and others, are as follows: Farm Buildings, Sanders Publishing Co., Chicago (from which pictures on pages 174–177 are adapted); Suburban Homes with Constructive Details, David Williams Co., N. Y.; The Farmstead, I. P. Roberts; Chapters in Physics of Agriculture, F. H. King; Plank Frame Barn Construction, John L. Shawver; Modern Carpentry and Joinery, Fred T. Hodgson; Modern Carpentry and Building, W. A. Sylvester; Barn Plans and Outbuildings, Orange Judd Co., N. Y.; files of American Homes and Gardens, published by Munn & Co., N. Y.; files of House and Garden, J. C. Winston Co., Philadelphia; files of the House Beautiful, Herbert S. Stone, Chicago; files of Carpentry and Building, David Williams Co., N. Y.; files of Breeder's Gazette, Chicago; Stable Sanitation and Construction, T. E. Coleman, London, 1897; Farm Buildings, W. J. Malden, London, 1896. Recent farm books are likely to contain useful suggestions on buildings; so also are bulletins of experiment stations.

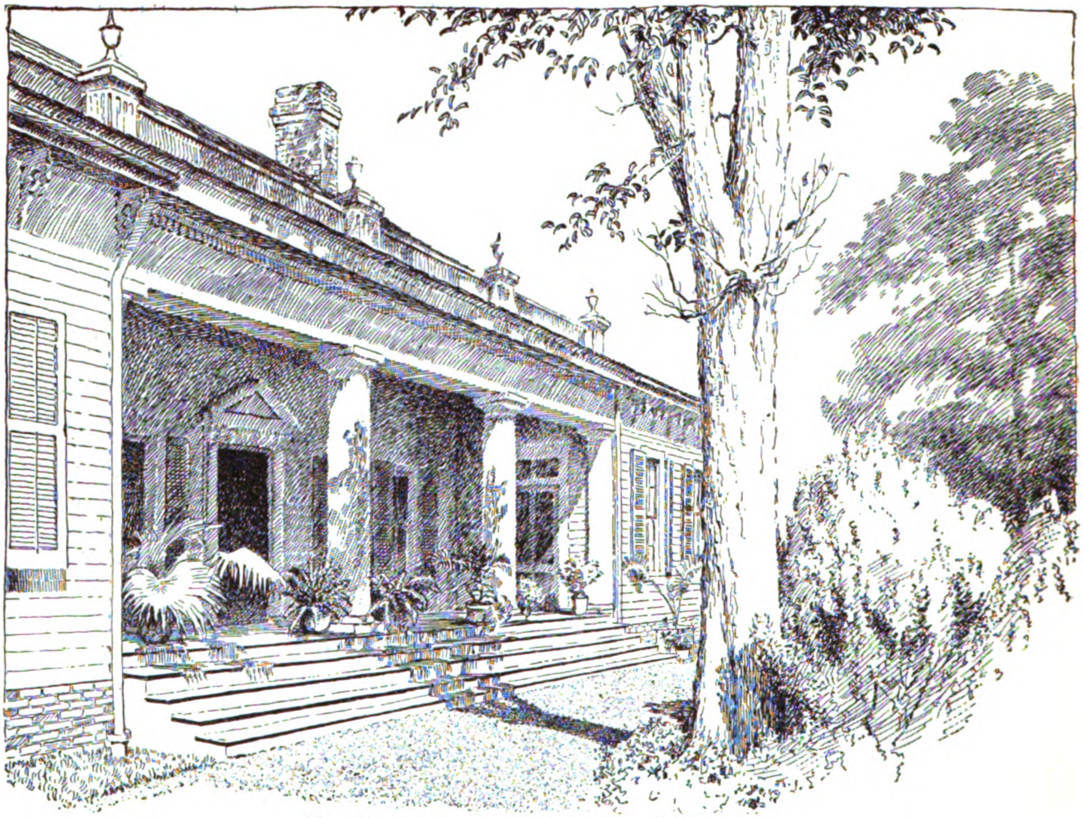


Fig. 293. A stately country house of the Southern type.

FARM DWELLINGS

By *Joseph E. Wing*

The purposes of a farm dwelling are several: To provide a place for administration of the farm; to afford protection; to house the various treasures and goods of the family; to be a home, that is, a meeting place for the members of the household, where they may come together for the family life. The building should also adorn the landscape. All this requires no elegance or costliness, but only a regard for fitness in form and design, and, above all, a suggestion of homelikeness, comfort and cheer within.

We are all more or less bound by inherited ideas as to the fitness of things—notions conceived by our forefathers to meet the conditions in which they were placed. So it is that we still have many forms and customs which, while perhaps the best for the conditions in which they were conceived, have now lost their adaptability. On the other hand, many of the inherited forms are still fit, and they meet well our modern needs. They appeal to us because of the memories they call up. For this reason certain kinds of architecture appeal to us, and other kinds do not.

When, centuries ago, men ceased living in caves, they built tents and shelters of bark. The tent introduced the ridge-pole. The first house had a long, slanting roof, with little wall. This roof idea became fixed in the mind. Beneath the low, long, sheltering roof were warmth, dryness and protection. To-day this low roof suggests homelikeness in the house. It is an ancestral memory and we not only like it, but are instinctively attracted by it, and the general effect of the house is pleasing.

To carry out the effect and at the same time to provide a necessity, there should be a generous chimney in the house. Chimneys are not so ancient as roofs, yet the sight of a goodly chimney, whether it is built outside the house or whether it merely emerges from the roof, suggests at once roaring fires and comfort within on cold days. From the point of view of the effect the house is to have on those who may look at it, the building should be kept low, the roof-lines made long and not much broken, the chimneys generous and not carried above the roof too far, suggesting factory chimneys.

The dining-room.

The room of first importance in the farmhouse is the dining-room. It should be planned first, and made ample. A width of 12 feet will suffice, but 14 feet is better. Greater width is needless. A length of 18 feet is little enough, and it may be increased as much as one likes. In general, 14 x 20 feet will be found a good size for a farm dining-room. Considerable fuel will be required to warm so large a room, and it is folly to plan a dwelling that will be unnecessarily expensive to maintain. It is well to plan the dining-room so that it may be used also as a family sitting-room. The dining table may occupy one end when not in use; an open fire should be at the other end, or at the side, and shelves provided, wide and capacious, for books and magazines in everyday use. There should be a plain, strong reading table, also, but there need be no book-case, as this will go better in the more formal sitting-room.

The dining-room should be located so that the sun will shine into it; and this leads one to think that it should have the eastern exposure. For summer use this side is best, for then it is delightfully bright and cheery at early breakfast time; but in winter the farm dwellers will generally eat breakfast before sunrise, and in the afternoon when the sun might come in at meal time, it will have gone around to the other side. All things considered, it is well to give the room a southern or western exposure.

The kitchen.

The next room in importance is the kitchen. This should adjoin the dining-room, or at least be not far distant. It should be sunny, light, and of not too large size. We no longer "try out" lard in the kitchens of farm dwellings, or do the family washing there. A large kitchen unnecessarily increases steps. A room 12 x 14 feet will be ample, and even a smaller room will serve. What the room lacks in size it must make up in conveniences. There must be, first of all, a ventilating flue. The kitchen chimney should be generous, with a smoke flue about 12 x 12 inches, and alongside that an air flue of at least as great dimension, running up through the roof. This air-duct should have a large opening into the kitchen at the level of the ceiling and near to the kitchen range. It will carry off a very great deal of the heat and vapors of the room, and all the smells will be drawn up if the doors communicating with the remainder of the house are kept closed. To accomplish this, all doors leading from the kitchen must have double-acting spring

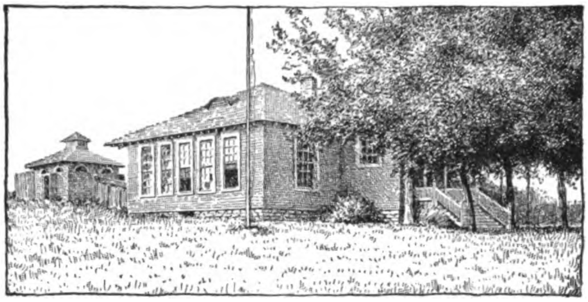


Fig. 294. Good proportions in a schoolhouse.

hinges, except, of course, the outside door. The kitchen must have a large enameled iron sink, provided with faucets and hot and cold water. These features were once the luxury of the rich. To-day they are within reach of almost all who desire them. They are sold so cheaply that no one has an excuse for not putting them into a good house.

Besides the sink, there should be a number of built-in cupboards and closets, where all sorts of culinary ware may be stored; and in convenient proximity, a pantry. The farm pantry should be of good size, and better if on the north side of the house, as that is cooler in summer. Between the dining-room and kitchen the housewife will take very many steps. Say the distance from the dining-table to the kitchen sink is only 20 feet, a very reasonable estimate, since it will often be much greater,—if the housewife carries her tableware to and fro, a few articles at a time, she will journey in setting the table about 400 feet, and in clearing it as much farther. Thus, in the three meals of the day, she will walk half a mile, or, roughly speaking, a distance of 180 miles a year in merely "setting the table" and "clearing off." Very much of this wearisome journeying may be easily avoided. There may be constructed a small serving table, strongly built, mounted on rubber-tired castor wheels, large ones of about 3½-inch diameter. The table may be 4 feet 6 inches long, and just wide enough to pass readily through the door. It may have raised sides that will prevent dishes from slipping off. On this serving table may be placed all of the things needed for the meal. It is easily trundled into the dining-room, and there it may remain during the progress of the meal, being laden again with the soiled dishes and rolled beside the kitchen sink after the meal is over. Such a table in the home of the writer has proved a very great convenience, while its cost was inconsiderable; the women folk would be very reluctant to part with it.

The woodshed.

In planning the farm dwelling, a generous woodshed should adjoin the kitchen, or perhaps be separated from it merely by a covered porch, so that access may be had without exposure to the weather. At one end of the woodshed a small concrete ice-house will be in order. Let the woodshed be on the same level as the kitchen. Near the door let there be driven a well to supply the drinking-water, and, if it is in a limestone region, a capacious cistern for supplying the soft, or rain-water. The writer has beneath the concrete floor of his kitchen-porch a cistern about 10 x 10 feet, which affords abundance of water for a large family, besides supplying the bathroom and water-closet. The rain from a roof over a house 42 x 43 feet keeps this cistern replenished. Rain-water is such a luxury that in digging the cistern one does well to give it generous proportions. Now that the use of concrete is so well understood, it is the simplest matter to make these square cisterns, covering them with a single slab of reinforced concrete. The expense is trifling when one considers the use. The writer has his cistern separated from the basement by a concrete wall, and thus can draw water in the basement by use of a faucet; there is also a simple force-pump connected with the cistern that forces water into a large steel pressure tank, where compressed air forces it through the house. The only opening in the tank is at the bottom, so that the air is imprisoned in the upper part, and its natural elasticity forces out the water with good pressure. This system of water-supply has worked perfectly, and, in the opinion of the writer, is superior to any other for country houses, since the water will not freeze in winter, nor become warm in summer, and there is no danger of leaky tanks imperiling the upper rooms. [For further discussion of water-supplies, see Chapter VIII.]

The basement and heating arrangement.

A basement of about eight-foot depth should be beneath the whole house. This will be inexpensive to construct, as not more than 5 feet of it need be excavated. The walls may best be of concrete, 8–14 inches thick, the thickness depending on the length of wall and nature and depth of outside earth; and a drain tile should be laid just outside the walls and a little lower. The floor will be of concrete, laid on a few inches of gravel, which should have free communication with the drain so that any seepage water will be carried off. Several divisions may be made in the basement, as there is need. One room having light and in a cool location will be adapted to keeping milk; it must have water and a good drain; and a cement water-trough in which milk and butter may be set to cool will be of use, the water to come from a convenient spring or from the well. There will also be a room for coal and one for fruit, the latter so arranged as to be easily kept cool. The heating of the dwelling may be from a warm-air furnace in this basement; when it is installed, the reason will be seen for the provision of suitable height, as otherwise the pipes will be a nuisance overhead. A better and more economical heat than warm air is hot water. This is more expensive to install, but its distribution of heat is good, and the water cools so slowly that the temperature of the house will not be so variable as when warm air is used. It may be said in favor of warm air, that it introduces into the house fresh air from outside, unless the furnace is arranged to use the air over and over again. The latter arrangement can hardly be too strongly condemned, for by its adoption the chief value of the warm-air furnace is destroyed and the health of the inmates jeopardized. Steam heat is also excellent.

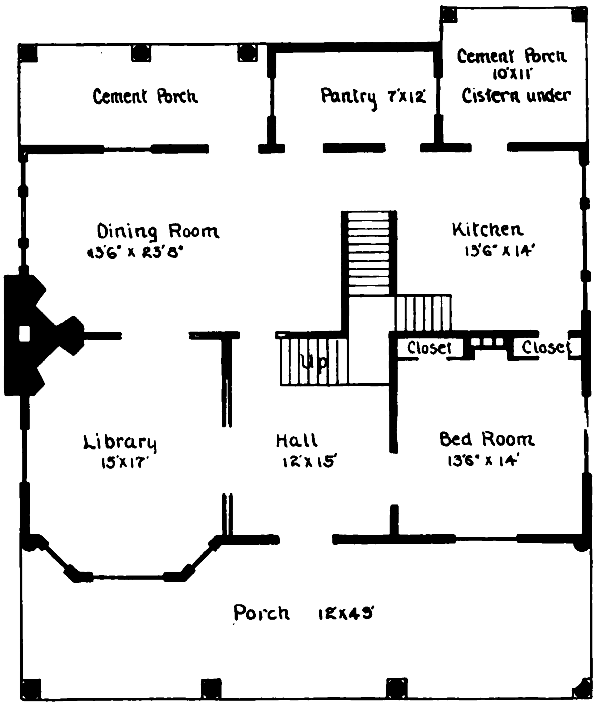


Fig. 295. Ground-floor plan of dwelling shown in Fig. 290.

An ideal arrangement is the combination of hot-water heating and open fires. Whatever system is adopted, there should always be at least two open fires provided,—one in the dining-room, another in the sitting-room, and, if possible, another in a bedroom. The benefit of the open fire is great. It affords a ready means of heat on chilly mornings of the warmer seasons; it gives great pleasure to the occupants of the room; and, most of all, it provides a sure means of ventilation, as the draft carries up great volumes of house air, taking, also, the colder air from near the floor. Open fires consume almost any sort of fuel. On the farm there is brush, rough wood, stumps, knots, and the like, all of which is useless for ordinary purposes, but it is all useful for the open fire. A good form of open fire is an iron grate with flues that convey fresh air from out-of-doors, warm it and send it out into the room, or into a room above. These grates are economical, and give comfort and ventilation.

It is hard to conceive a situation where an open fire would not be desirable, for even in the southern regions there are cool and damp days. In the frozen North, where for so long a time the women and children are imprisoned within the house, it is almost essential to their health and vigor that it be provided. In cold regions no attempt should be made to use the open fire alone to warm the house, but it should be used in connection with a stove, steam or hot-water heater, or warm-air furnace. In building a warm-air furnace, it is important that the pipes or boxes that bring in fresh air be of ample size, and that they be absolutely air-tight where they pass from the outer space through the basement to the furnace, or there will be the likelihood of dust and unpleasant air entering and being distributed over the house.

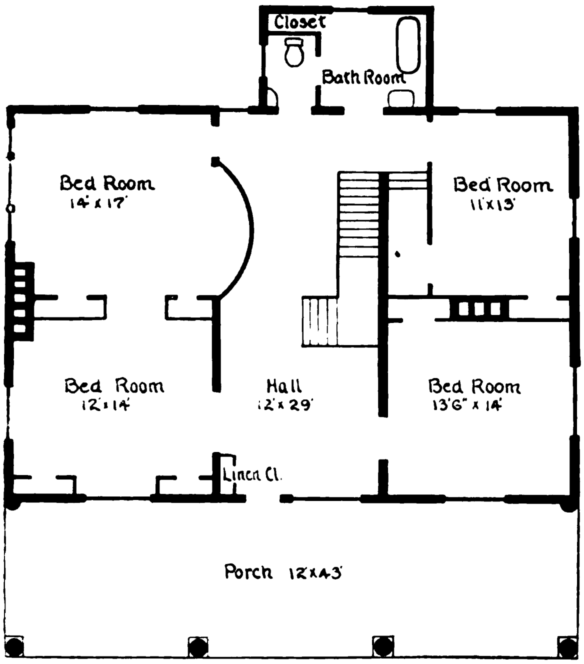


Fig. 296. Plan of the second story of the residence.

There is no need of any specific ventilating system if the open fireplaces are used, as they will amply suffice for the removal of foul air, and a fresh supply will be constantly drawn through crevices about doors and windows, unless a place is made for it to enter, as through the warm-air furnace, or through the flues of the ventilating grate. It is worth noting that statistics show an alarming increase of tuberculosis in the New England states coincident with the closing of the old fireplaces and their replacement with iron stoves that heat the air without affording any ventilation or change. If there are no fireplaces, some means of changing the air should be provided, aside from the haphazard and ineffective opening and closing of doors and windows. Fresh air may be admitted in the walls, as in the "King System" of ventilating stables.

A specific example.

The general arrangement of the house should be as compact as possible. This secures the most room at a given outlay, and the greatest convenience in the use of the dwelling. One should avoid a long, rambling building, with many ells and projections. Such a form is more costly to build and is more expensive to warm. It is more difficult to keep cool in summer than the compact, square or rectangular house. Reference to the plan in Fig. 295 will illustrate a compact farm dwelling, of moderate cost, discussed here not for the purpose of recommending this particular plan, but to illustrate how the various problems have been met in one instance. There is at the front a porch the length of the dwelling, which in this example is 43 feet. This porch is 12 feet wide and 8 feet 3 inches high, as are the rooms of the ground floor. A porch of this kind when plainly built is not expensive, and is a good living-room for several months of summer. It has a floor of concrete which will never need repairs, columns of concrete which never rot or need painting, and a railing of concrete. The writer built these posts and railings, assisted by a carpenter to make the forms, and their cost was very moderate, while they are now built to endure for all time. This porch cost in concrete much less than it would have cost in wood.

As one enters the house he finds a hall 12 feet wide, from which leads the stairway. A wide hall is useful, convenient when one has callers whom he may not care to take into the sitting-room, and gives dignity and expression to the house. There is great value in first impressions, and a generous hall, simply furnished, with one or two good pictures hung on its walls, makes the stranger aware at once that he has reached a home where there is culture.

From the hall the sitting-room, dining-room or down-stairs bedroom is entered. A bedroom on the ground floor is most useful when there are old people in the family. This room may of course be turned to other uses; it may be made a library or parlor if such is desired, or a study and office for the man of the house, where he may keep his books and records, and receive and pay his laborers.

The stairs are wide, with steps of low ascent and easy tread. As the lower story is only 8 feet 3 inches in height, there is no great climb to the upper floor. It is essential in a country dwelling that the lower story be not too high, as by keeping it low much needless stair-climbing is avoided and some fuel saved in winter. Nor is a house of low ceiling less "airy" than one of high ceiling, so long as provision is made for ventilation. The day is past when we bottled up enough air in the houses in the fall to last them till opened again in the spring. Now the air of a whole house is changed several times a day, and there is no reason for high ceilings. If they are desired, let them be in the rooms above, though even there they are useless.

At the top of the stairs (Fig. 296) is the bathroom, where it is of easiest access from any part of the house. The bathroom should always be divided to form two rooms; in one, which may be very small, will be the closet and a simple basin for the hands; the other and larger compartment contains the bath-tub, a larger lavatory, medicine chest, towel closet and the like. The value of this separation is very readily seen in a family in which many members may rise at about the same time. For the comfort of the housewife and her convenience in doing the chamber work, there must be provided a laundry chute from the bathroom down to a clothes-bin in the basement. This chute may be of smooth boards, about 8 x 10 inches inside measure, with a hinged cover. Through it all the soiled linen and towels will be dropped, and not only many steps saved but much annoyance from littered rooms and mislaid soiled garments.

The bedrooms are of moderate size; there is nothing gained by making a bedroom very large, nor should it be too small. Twelve by twelve feet will do very well; if a little more room can be given, it will be better. When water is in the house and plumbing is being done, it is well to put stationary wash-stands in some of the rooms, or simple lavatories having hot and cold water. These may be in corners where they will take little room. It will be found that these permanent fixtures cost less than good wooden wash-stands and toilet sets, besides being far more convenient. In building bedrooms, windows must be arranged so that there will be space to place the bed between them.

Closets are an essential part of each bedroom. They should be of as generous dimensions as possible. There should also be a linen closet in the hall, where bed linen and other fabrics may be kept.

There will be needed a back stairway, leading to the kitchen or to a back hall. In the plan under consideration the back stairs leaving the kitchen join the principal stairway at a landing. This economizes space and proves satisfactory.

In referring to the plan of the upper floor, Fig. 296, it will be noted that the hall is of generous width. This might at first be thought a waste of space, but it is not really so, since there is placed at one end of it a couch, which on occasion opens to a folding bed. This upper hall is a delightfully cool place in summer, and by it the house is relieved from the appearance of being contracted and cramped for room.

The upper porch, of the same size as the lower, 12 x 43 feet, is one of the chief charms of this house. It is not an expensive addition, for it requires only four concrete columns with the railing and the floor. The same roof covers it that would cover a simple one-story veranda. In the home of the writer, who followed this plan exactly, the upper porch did not cost more than $200. It affords an excellent place for the good housewife to sun her bedding; in summer it is the private resting-place of many of the household, and it is the sleeping place of all the male members of the family from May till middle October. Wire screens enclose the porch, as they do the one by the kitchen door, so that there is no annoyance from insects. No better preventive of lung trouble or tuberculosis can be found than sleeping out-of-doors. And no better investment can the farmer make than to provide a place where his family may enjoy this privilege.

In the house under consideration there is a very large room on the third floor that may be finished into additional bedrooms if needed, though they will have the demerit of being rather warm in summer, as they are so near the roof.

Considerable space has been given to the description of this house, as the writer, after many years of study of house-building for the farm, came to this plan, and adopted it as being all in all the best that he knew for an average family of five to eight persons, in average well-to-do circumstances. The house cost less than $4,500, with floors of hard maple, trimmings of yellow pine, good but not expensive plumbing and bath fixtures, a water-supply on the pressure plan and a warm-air furnace, with two ventilating grates.

Concrete construction.

In the construction of country dwellings, it is well to make considerable use of concrete when gravel or crushed stone is to be had and cement is not too dear. A dry cellar is essential, and to make it so there should be a tile underdrain all around the wall and a little lower than it, as already explained. This drain should have a good outlet. If the excavation has been made just large enough to admit the wall, and the concrete is thrown directly against a clay bank, there is serious danger that it may pack so closely that water can not go down beside the wall, and will find its way through instead, making the cellar damp after heavy rains or melting snows. To prevent this is a simple matter. The excavation should be so large that there is about 4 inches outside the wall; and as the concrete is thrown into the form which builds the wall there should be loose gravel, with no cement, put carefully next the clay. To insure a neat job and perfect limitation of concrete and gravel, a 12-inch board may be used to separate the concrete from the gravel; as the wall is filled this board may be raised, the gravel holding the concrete in place. Thus the water will find its way downward through the loose gravel to the drain, and the cellar remain dry.

The concrete walls should extend to the top of the cellar; and if the builder has time and command of labor of sufficient skill, the whole house may well be built of concrete. The cellar wall may be built solid, 8 inches or more thick, or it may be built hollow, each part 3 inches thick, separated by a 10-inch air space. This wide air space is conducive to warmth and dryness, and as air is abundant and cheap it costs little to enclose it. It is far easier to build a wide air space than a narrow one. The forms for hollow walls are made by setting for the inner form a 2 x 6-inch studding, with a 2 x 12-inch plank on each side of it to restrain the concrete. The studding, being wide, is loosened by a twist, and the planks raised for the next course.

The two walls are frequently tied together by metal reinforcement, and occasionally by concrete. Concrete walls are cheap when built by farm labor, but expensive when built by high-priced contractors. All concrete work should be well reinforced by steel rods. If the farmer has time to devote to house-building, and gravel or broken stone is at hand and cheap enough, he will build of concrete at about the same cost that he would build of wood, and save much after-expense in repairs, paint, fuel, and the like.

The outside of a concrete house, or even foundation wall above grade, should not be left as it comes from the board moulds, for it shows the marks of the boards and looks unfinished and ugly. A coat of mortar may be floated on the wall; or, better, a coat of rough-casting may be added. The mortar or rough-casting will stick to a wall that is not too smooth. The rough-casting makes an attractive surface; it is best also for an outside coat on expanded metal lath.

In concrete construction of dwellings, the inner walls will be of solid concrete 4 inches thick, reinforced with steel, and the floors may well be of the same material. They need not be more than 4½ inches thick, and for spans of 14 feet should be designed to have metal reinforcement of ½-inch iron bars, spaced 5 inches on centers. This will give strength to support a load of 480 pounds per square foot, a strength very far in excess of what would ever be needed in a dwelling.

The concrete floors should be covered with thin wood, the strips to hold which should be laid in the concrete. The expense of concrete floors would not be great, the element of time in their building being the most serious matter, as the concrete should set for at least thirty days before having its supports removed. The advantage is that there would be no noise of footsteps on the floors; there would be almost no danger from fire with walls and floors all of concrete, and one could safely neglect fire insurance, since the roof would be all that could burn. In case concrete floors were adopted, the ground floor and the one above would be especially suited to its use; the kitchen floor might well be left in very smooth cement, which may be troweled to resemble marble.

The interior finish.

In the choice of woods with which to build, there is economy and sense in choosing native woods for finishing, but they need at least two years of seasoning before being worked. It is wise, therefore, for the prospective builder to saw his wood and very carefully "stick" it up to dry in some airy place two years before he breaks ground. Birch makes a beautiful finish; sycamore is very pretty; butternut or white walnut is soft and attractive; maple is sometimes used, but is hard to work and does not hold a finish well, owing to its extreme impenetrability; catalpa wood makes a good appearance; common cottonwood takes a fine finish, but is soft and easily indented; beech is very hard, but may be used; hickory is hard to work, but makes a neat floor that will wear like iron. The various kinds of oak are the most satisfactory of all woods for interior finish. White oak has a fine grain and great beauty; it takes stains and finishes readily owing to its porosity, and is at the same time hard and durable. An oak floor is worth what it costs if one can afford it. Next in choice comes maple, which is beautiful and indestructible from wear, but, as already stated, does not well hold a finish. Bur-oak is of interesting grain. All oaks should be quarter-sawn when possible, since the wood is more durable when laid in this way and also of greater beauty.

Concerning hardwood floors, which some country persons think they can not afford, it is noteworthy

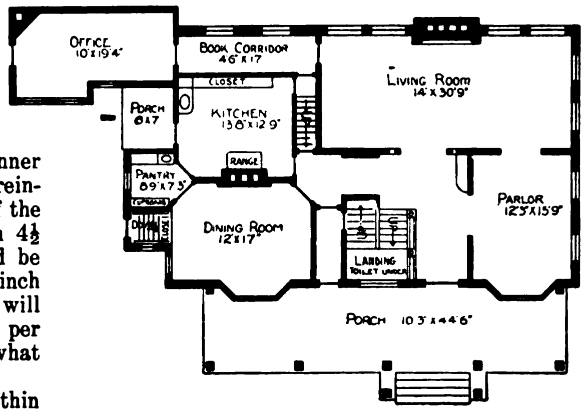


Fig. 297. Ground-floor plan of dwelling shown in Fig. 284. The office or "den" is an important adjunct to a modern farm dwelling, providing a place for administration and obviating the necessity of receiving all callers in the residence part. It should have an outside door and be accessible from the barns and fields. In general, it is better that the kitchen have more than one outside window, but in this case there was special reason for setting off the kitchen from the side yard.

that some of the new homes of the rich are floored in part with wide oak or other hardwood boards, as wide as can well be secured, which are often nailed down with large-headed brass nails, the nails showing. Almost all country persons can have these wide boards, an inch thick, for the cost of sawing and laying carefully away on sticks for two years to dry. They need not be tongued and grooved, though it is well if this can be done. The use of hardwood floors and the abolition of nailed-down carpets banishes forever that ancient terror of the household, "house-cleaning time," as the house is always clean by the outlay of very little energy in shaking rugs and wiping up smooth floors from week to week. And there is no doubt that such a house is far more healthful as a place of abode.

The finish of the interior woodwork should be all in natural effect, with perhaps a little stain to hasten the beautifying that time brings. Linseed oil, which painters advise against, if used for a first coating adds greatly to the density and hardness of the wood, and in time helps it to color and gain richness of appearance. It is better for floors first to be well-saturated with linseed oil, and afterward they may be waxed, or lightly oiled occasionally.

The exterior finish.

The outside of the house, if it is of wooden construction, as most houses must be, may be finished with matched or lap siding, with shingles or with plaster. Beneath the boards there should be used the best of cold-resistant building-papers. Some of these are double and quilted with eel-grass, and have great warmth. A dollar spent in keeping out cold will save ten spent in coal. The most easily applied covering is doubtless wooden siding, which must be frequently painted and therefore lacks in ultimate economy. Paint is at best more appropriate in towns and seldom is in keeping with rural surroundings. Shingles well put on look exceedingly well on farm dwellings, though of course they are more adapted to certain classes of buildings than to others. The use of stains, of which the creosote stains are probably best, instead of paint on the exterior woodwork of a country house, is a commendable practice, for stains are far more beautiful than paint and endure longer, besides preserving the wood quite as well. Shingles need only staining, and near the sea the salt air imparts a stain so that they need no other brush than the kindly one of Father Time.

Plaster for outside use is the best covering in the warmer and drier parts of America, and in appearance it harmonizes well with the environment of tree and vine. It is the most economical of all coverings, for once carefully put on it needs thereafter neither paint nor repairs; and vines will cover it over and give much beauty at no cost but the planting.

There are certain essentials to successful outside plastering of wooden houses. They should not be plastered until the wood in them is dry and has ceased to shrink. The studding should be covered with some sort of wooden sheathing; anything cheap will serve so long as it is dry and not inclined to warp. Then the lath must be of metal, and should be of galvanized material. There are various makes of metal lathing. Some persons use for outside plaster the plain galvanized woven wire such as is sold for poultry fencing, with about 1½-inch mesh, or smaller. This netting is stretched tightly over the wall to be covered, and stapled securely with staples 1½ inches long. The wire netting must not touch the wood but be spaced away from it about one-half inch. This is accomplished by nailing on strips of ordinary plastering lath, placing them about 24 inches apart. Or the netting is held out by the use of common slotted wood screws 1 inch long, the wire of the netting being inserted in the slot and the screw driven in a little way. Wire netting must be stretched sideways, not the long way. The expanded metal lath is, of course, superior. Plaster applied on ordinary wood lath will crack, because the lath expand and shrink with moisture conditions. In fact, all plastering, inside and outside, should be on metal. The composition of the plaster may as well be of lime and sharp sand, and it may not be necessary to add portland cement to it. It is put on in two-coat work and left rough by a wooden "float" or trowel. There must be metal flashings over all doors and windows.

Lime and sand plaster exposed to the weather hardens for several years. If it absorbs rain on exposed surfaces it may be waterproofed by a washing of portland cement and water, as heavy as thick cream. There are outside plasters made of portland cement that are better than the one described, though they cost considerably more and require more skill to put on.

The cost of applying outside plaster is not more than applying two good coats of paint, and the investment is a permanent one, as good outside

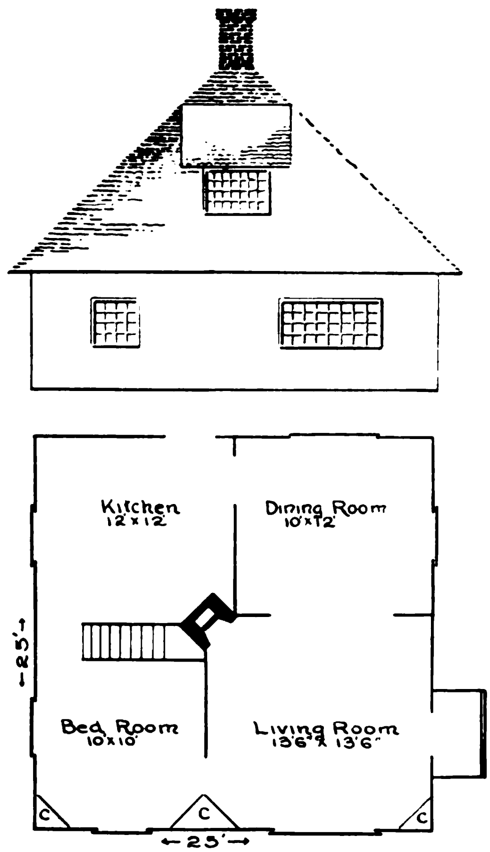


Fig. 298. Elevation and floor plan of a laborer's cottage.

plaster will endure for centuries. It is cool in summer and warm in winter, and gives a very pleasing surface for a country dwelling. There are many old houses that need repainting, that are cold and drafty, many of which may be cheaply covered with plaster and made as good as new at less than the cost of thorough painting.

Tiles are the best material for covering roofs, but their cost is yet rather excessive for general use. Slate is durable, but not often of the right color to harmonize with the surroundings; shingles, when carefully dipped in hot linseed oil, last for half a lifetime; all the metal roofs are out of the question for a dwelling, both because of their appearance and because of their expense, their frequent need of repainting and the heat they impart to the chambers beneath them. Some of the prepared roll roofings may be used for temporary roofs, but they do not add to the good appearance of a dwelling.

Laborers' cottages.

It is sometimes necessary to provide rooms in the farm dwelling for laborers. This practice is becoming increasingly rare, and it is now the custom for laborers to live apart from the farmer's home; but in case it should be desired, it is well to provide a wing separate from the remainder of the house, preferably with no passage connecting with the family apartments. Far better than to keep laborers in the home is to provide them with comfortable buildings of their own; and it will be found that this is both more economical and more satisfactory to the men. A suggestion for a simple laborer's cottage is given in Fig. 298.

There is no reason why the small farm cottages should not be neat and attractive in appearance. They should have sufficient land to permit of a dooryard, trees, shrubs, fruit, flowers and a good garden in the rear. The plan suggested in Fig. 298 is of a well-designed and neat-appearing cottage, 25 x 25 feet, with four or five rooms, that can be built for $400 to $700, according to materials used and location. A woodshed may be added at the kitchen door. The cottage should be built in plaster construction.

Summary.

Whatever the means of the farmer, when he comes to build he should bear in mind the few essentials in a country house: a generous living-room that may serve also as a dining-room, an abundance of light, some open fires, a broad, rather low roof not much broken, generous porches, which may be of the cheapest material so long as they shelter from midsummer sun and permit the living out-of-doors, and, if possible, some place where the family may in warm weather sleep out-of-doors. Chambers immediately beneath roofs are hot and disagreeable, and conduce to unhealthfulness.

CONSTRUCTION OF BARNS, WITH PARTICULAR REFERENCE TO SANITARY DAIRY STABLES.

By *H. E. Cook*

It is safe to lay down the broad principle that live-stock, whose bodily function is one of production, must have comfort in the fullest sense if the animals are to return a profit to the owner. If we expect a continuation of bodily strength equal to the increased demand on it, we must not only approach but actually improve on that season of the year when nature provides the most favorable conditions for production and for the support of the young. It is possible for owners of live-stock, and especially those who keep dairy cows, to keep their stock all the time under conditions that are an improvement on the month of June. The idea in stable construction is not to make the stable conditions more comfortable than the few ideal June days, but to protect the stock from storms and to provide the three essentials—a uniform temperature of 55° to 60°, an abundance of light, and pure air.

There is little use in undertaking a task unless the point of view is correct. It should be realized

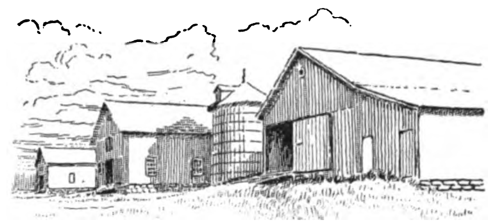


Fig. 299. Exterior of barns in northern New York. (H. E. Cook.)

that the stable is the constant home of the animal during not less than six months of the year in the dairy sections of the country, and the place of business for the care-taker during the working hours. It is as much a physical impossibility for a dairyman to reach the highest efficiency in dairying in an ill-arranged, dark, damp stable, as for any business or professional man to attain the desired result when laboring under similar disadvantageous environment. Why should the dairyman so tenaciously cling to a milk-producing establishment unfit for the production of any other human food? The most susceptible of all foods to poor conditions is ordinarily produced under the most unfavorable surroundings.

Again, from the presently accepted knowledge of animal disease, especially tuberculosis, there comes no surer or safer immunity than sanitation in the quarters in which the animals are housed. Were he to ignore entirely the humanitarian side of the question, there should come to every cow-owner from the purely materialistic standpoint a desire so to build and arrange his stable that the highest ideals will prevail.

Difficult and perplexing notions should not be entertained—various compartments with elaborate stall devices, posts and dust-catching corners. On the other hand, an effort should be made to eliminate every obstacle on which or by which dirt or

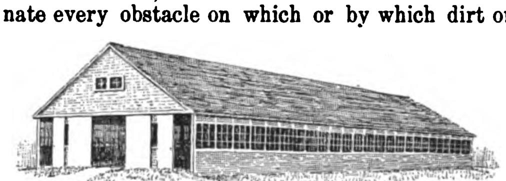


Fig. 300. Ideal lighting for a dairy stable.

dust may be gathered. Simplicity begets cleanliness. Tradition builds but for confusion. Modern sanitation tears away every obstacle and rounds the corners.

The cow stable should be subject to no greater fluctuations of temperature than the homes of the owners. A stable that is subject to the changes of outside temperature is, in varying degrees, nothing more or less than a modification of the primitive windbreak for stock.

The building of a cow-stable, then, is not an isolated undertaking. The structure is to be the expression of the farmer's philosophy or point of view in respect to the general management of his farm. A cow-stable is also only one part of a complete barn construction. The general objects to be attained in barn construction are stated as follows by Professor Hunt (Bulletin No. 30, Cornell Reading-Course for Farmers): (1) To keep animals and other objects dry; (2) to maintain a proper temperature; (3) to secure pure air, with a proper degree of humidity; (4) to provide light; (5) to secure cleanliness; (6) to prevent the breeding of vermin (rats, mice, insects); (7) to preserve the manure; (8) to secure health, comfort of the animals, freedom from injury, and to prevent the spread of contagious diseases; (9) to secure economy in feeding and watering; (10) to provide economy of space; (11) to maintain economy of labor; (12) to secure economy of construction; (13) to secure strength and durability; (14) to present good appearance. A discussion of modern cow-stables will explain how some of these objects may be attained. [Figs. 306, 309, 314, 315, 323, 327, 329, 330, 331, 332 are from Professor Hunt.]

Provision for sunlight.

The ideal location of a cow-stable in New York latitudes is shown in the plan in Fig. 303. The aim is to secure the admission of as much sunlight as possible, for without this, continued health and sanitation can not be maintained. It will be observed that the building has a gentle turn to the southeast, thus giving the animals the benefit of sunlight during the whole day. Windows should be placed on the east, south and west sides. Windows are not so necessary on the north side, although in some cases it may be desirable to secure the full complement of four square feet of window space to each one thousand pounds live weight of animals.

The windows should be made and put in like the ordinary house window, two sashes in each opening. They should be fitted to raise, slide or swing at the will of the owner. They should never, under any circumstances, be opened in the winter. An additional single sash should be put in each opening in the fall and fitted tight, to prevent dirt and moisture accumulating in this dead-air space between the double windows. The difficulty of frost and moisture will thus be avoided.

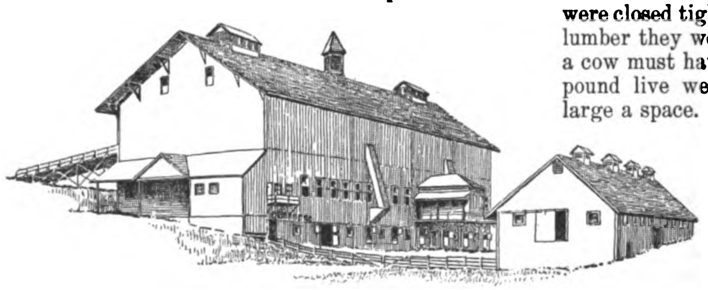


Fig. 302. A commodious Oregon dairy barn.

The practice often followed of using one side of the stable for hay or straw storage cannot be approved if it results in cutting off the sunlight. To illustrate, it would not do to build the barn 50 feet wide, 36 feet of which will be taken for two rows of cows, and the extra width of 14 feet used for hay storage, thereby cutting off light from that side. Neither is it wise to build a shed or any protection over the windows. The width of the stable should be confined to the actual working space.

Fig. 301. A good type of dairy barn, on a representative southern farm. The conception of such a stable is fundamentally different from that on which the old barns are built.

The interior arrangement.

It will ordinarily be most economical of space and of time in caring for the cows to have two rows. A building 36 feet wide, outside measure, is ample. If the ceiling is 8½ to 9 feet from the floor there will be about 500 cubic feet air space for each mature cow. This is only half the rule laid down by authorities in the past. However, it is all the space a cow can warm with the heat of her body when she is in a constant change of air. One has to trace the history of stable construction to understand the mistakes that have been made. In the early days, stables were very small, providing less than 200 cubic feet of air space for each cow. Small apartments were better in the loosely constructed stables of the early days. But when the stables were closed tightly with building paper and matched lumber they were unhealthful, and it was said that a cow must have a cubic foot of air space for each pound live weight. Few farmers could afford so large a space. The wealthy tried it, building mammoth stables having an air space per cow that was beyond her power to warm. The ceiling was made of sound lumber, shutting off every avenue for air to escape. The result was that condensation took place and the stables were both cold and damp—breeding grounds for tuberculosis. If artificial heat had been provided no trouble would have followed. The point to keep in mind, therefore, is to build a stable that has only as much air space as the cows can warm, and yet has sufficient floor space so that the work can be done handily.

The stable must be provided with box stalls, with partitions just high enough to keep the animals in. These are a necessity for the proper care of cows at calving and thereafter. Space should also be provided for calves, for young animals and for service bulls. Other necessary features are feeding passages 6 feet wide; a driveway 9 feet wide for hauling manure; standing platforms $4\frac{1}{2}$ to 5 feet wide, depending on the size of stock kept; gutters 16 inches wide and 8 inches deep on the side of the cow platform and 6 inches deep on the side toward the drive. The size of the gutter may be varied somewhat to suit the owner. The dimensions here given will be found satisfactory under most conditions.

When providing for two rows of cows, whether they shall face in or out will depend somewhat on methods of summer feeding. If soiling is the practice, there will be an advantage in feeding to have a single passage suffice for hauling in green feed. When the summer pasture prevails, and the feeds are already in the barn, a saving in hauling manure and a saving in floor space will result if the cows face out, with a single manure drive. The stable will have less floor space for daily cleaning. The platform space will depend on the cows. The

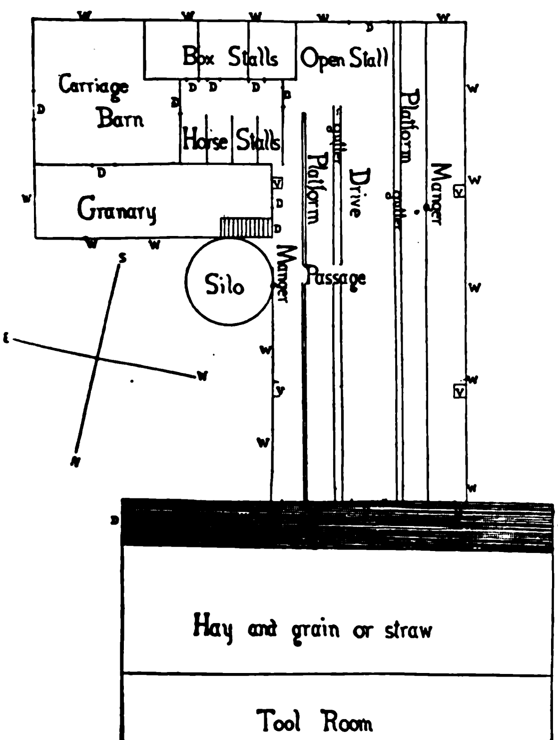


Fig. 303. Plan of a sanitary dairy stable. Exterior of this barn is shown in Fig. 299.

1,000- to 1,200-pound cows should have nearly four feet width, smaller cows less. It is a very small cow that will not need three feet in width.

Nothing is more objectionable in a sanitary stable than unnecessary internal machinery. If a partition is necessary, an iron pipe may be attached to the upper stanchion frame and thence to the floor between the cows, about half of the distance from neck to gutter. Mangers are not desirable. In a warm stable, when succulent food is used, they are not easily cleaned and soon become sour and nauseating. A smooth, clean floor is best. With a little effort cows can be arranged in such a way that they will not get more than their share of the feed. A depression in the floor is nothing but an apology for a manger. Mangers can be used to advantage only when a few cows are kept and the feeder does not remain with the cows. It may safely be said, however, that if the barn is so unpleasant that the feeder does not care to remain with the cows during the time in which they eat their grain feed, or if he is absent for any other reason, he will never become a successful dairyman. It will be noticed in the floor diagram (Fig. 305) that the cows stand on a platform with a rise of $1\frac{1}{2}$ inches in 3 feet from the gutter. All liquids are therefore carried quickly into the gutter, and there is no strain on the back and kidneys of the cow as there is when she stands for a long period on an inclined plane. The drive platform should be gently crowned so that any liquids falling on it will at once find a way to the gutter. A concrete manger built high enough to retain the feed appeals to many. There is no objection to it from the sanitary viewpoint if it is kept clean.

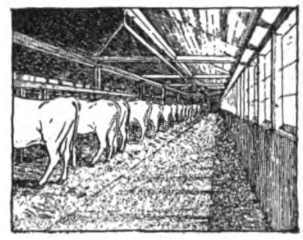
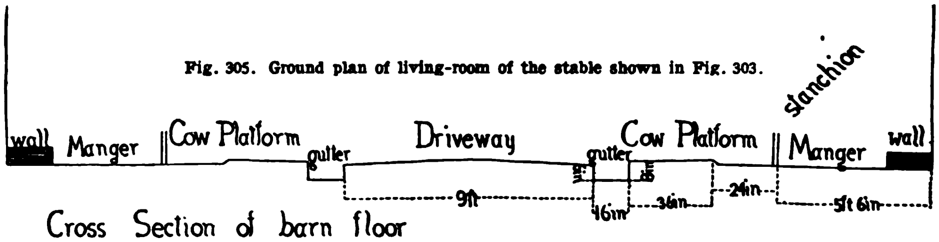


Fig. 304. Stable of Walker-Gordon Company, Plainsboro, N. J., showing a "flood of light."

A water-trough can be built into the floor, and into this water may be drawn at regular intervals. The objection is that it is seldom cleaned sufficiently before watering and the cows are forced to drink wash water. The drinking buckets in common use have the advantage of economy of labor, but the disadvantage of quickly getting filthy. They should be kept clean. The writer has in use a very cheap and simple method of watering—a mounted trough from which five cows drink at once. Water is admitted from a pipe running over their heads on the stanchions. The water is always fresh and pure. This device has the one objection of taking more time than would be necessary for watering with buckets. If a high concrete manger is provided, a permanent continuous water-trough can be built near or at the top, with covers each the width of a stall, enabling the animal to open the lid and drink at will. The cover should be adjusted to drop at once when the animal stops drinking.

In the opinion of the writer, swing stanchions are the most desirable fasteners, all things considered. He has in use a simple device for holding the movable piece, that can be attached to any make which has not been so built, so that the difficulty of always finding the movable piece where it is not wanted has been overcome (Fig. 307). These may be built of wood; or some of the more neatly constructed iron stanchions now on the market be purchased at a moderate cost. They should be hung with chains; the pivot fastener is no improvement on the old rigid fastener.

Fig. 305. Ground plan of living-room of the stable shown in Fig. 303.



The foundation walls and floor.

Concrete is the only material that meets the three requirements of sanitation, durability and economy. It also possesses that much-to-be-desired quality of being fire-proof. Prejudice against it is fast dying out and its merits are becoming generally appreciated. While concrete construction is comparatively simple, it is not an art into which guess-work can be mixed with safety. Portland cement and clean, sharp sand are requisites. Grouting or foundation work can be made of gravel, crushed stone, or of small field stone, often called "hard heads." When obtainable, these last are much cheaper than crushed stone or gravel, since they require less cement to hold them in place.

In making the floor, the space to be floored should first be leveled. If it is soft dirt, it should be drained and solidly tamped. Ordinarily, sufficient drainage will be given by the trench under the barn wall. If there is any doubt, a run of tile drains should be put through the center of the building. The trenches are lined through, a ditch 2½ feet wide and 1½ feet deep dug, the smali field stone of about five inches in diameter hand-laid to an upper line, then filled in with a mixture of portland cement one part and sand five parts. This should be mixed dry and be made wet enough to enter every space between and under the round stones. The whole should be tamped to insure firmness. Walls are laid up on each side exactly twenty inches apart. Then there is put on the bottom, before the foundation is dry, two inches of mortar made of portland cement one part, sand two parts, dry mixed and with enough water added to make it spread easily. As soon as this is set a box is put on it 16 inches wide, 8 inches high on one side and 6 inches on the other. The two-inch space is filled with a finishing coat of two parts portland cement to one part of sand. After the cement has set, the form is taken out and the gutter troweled smooth with cement and sand, equal parts. The remainder of the foundation can be laid in the same way. The surface should not be left smooth. After it has set, but before it has hardened, it should be finished with a small board trowel which will give a sandpaper finish to all parts where the animals walk. This does away with all danger of slipping. In any part of the building that is subject to freezing temperatures the floor should be laid in checks about 3 feet square. The finish coat should always be laid down before the grout has hardened, and may vary in thickness from one to two inches, depending on the strain to which it will be subjected. For example, a granary floor and feeding mangers may be finished light. The drive between the cows should be heavy, including gutters; the cow platform may be finished medium. There will be less danger of the horses slipping when hauling manure on sleighs if at least half of the driveway nearest the outlet door is grooved or creased. This makes the driveway harder to clean, however. The whole passage may be grooved if it is thought desirable. When one or two steps are needed to reach an elevation, they should be of concrete. The barn wall should be covered where it projects into the stable so that every part will be smooth, easily cleaned and offer no shelter to mice and rats. The granary floor should be of this same material, and should be laid in checks if there is danger of freezing under it. The stanchion bed-piece may be made of concrete, thus avoiding a dirt-catcher. Wherever a partition is to be built, short pieces of ¾-inch iron pipe should be anchored, projecting above the finished floor 1½ inches. On these may be placed a 3x4 scantling and the superstructure built.

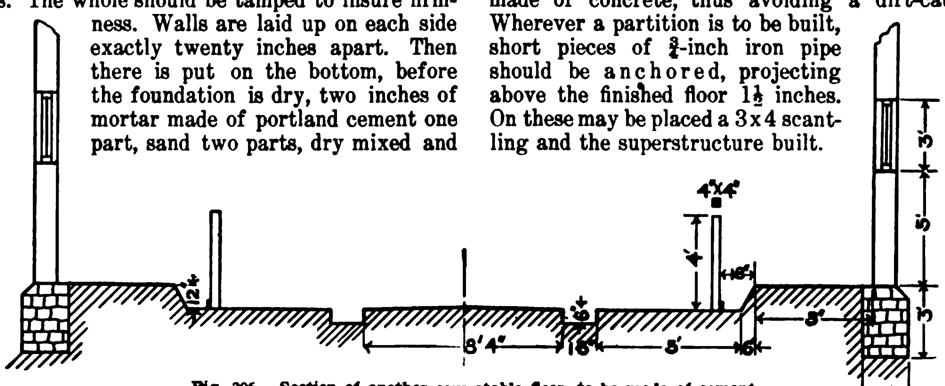


Fig. 306. Section of another cow-stable floor, to be made of cement.

If small field stone are not at hand, gravel or crushed stone may be used instead, six parts to one of cement. This should be put down 3 to 4 inches thick, firmly tamped, and the surface coat applied as suggested above.

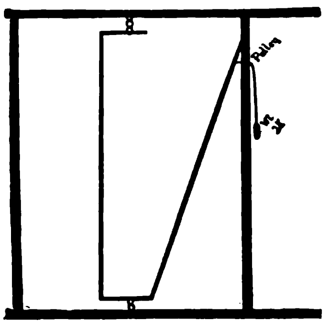


Fig. 307. A good stanchion device. The weight on the end of the pulley is two and a half pounds. It serves to keep the movable piece always in one place when not fastened.

A plan has been recently tried and recommended by Mr. S. Stewart, of Newburgh, N. Y., of laying three thicknesses of single-ply tar paper over the grouting and under the finishing coat, each course covered with coal-tar paint, thereby nearly destroying the non-conducting disadvantage of concrete. The writer has not used or tried the plan, but he feels free to advise it on the recommendation of so high an authority on the use of concrete and the construction of sanitary dairy buildings.

It is impossible to give exact figures as to the cost of cement construction, because the farmer will rarely hire the work done. About twelve cents a square foot will cover the entire expense of a cement floor built in a substantial manner. Much of the work can be done at odd times, thus reducing the money outlay by half. It is not advisable for any one not possessing a mechanical turn of mind to lay the finishing coat. He may make it hard and durable, but it may lack that true-to-line finish which makes cleaning easy. It must be remembered that a properly built concrete floor should last a lifetime. If it is not built properly it will be a constant source of trouble to man and beast. The writer has concrete floor in use under cows, horses, hens and pigs, and it is successful in each case. While concrete makes sanitation possible, which cannot be said of plank, it also allows for the perfect saving of all animal excreta. The oft-heard objection to cement, that it is cold, is as true to-day as ever. Cement is cold not because it has a lower temperature itself, but because it is a rapid conductor of heat, unlike wood, which is a non-conductor. A thin covering of any non-conducting material, as dry shavings, sawdust or straw, will insulate it and keep it from chilling the animals. No kind of domestic live-stock should lie on bare cement. A serious objection to a plank platform is that the soaking of liquids and the wear under the hind feet make cleanliness impossible. All this is done away with when cement is used.

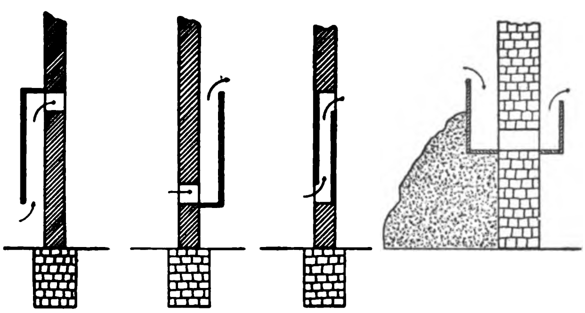


Fig. 309. Modes of admitting air into a stable. That at the right shows a basement wall.

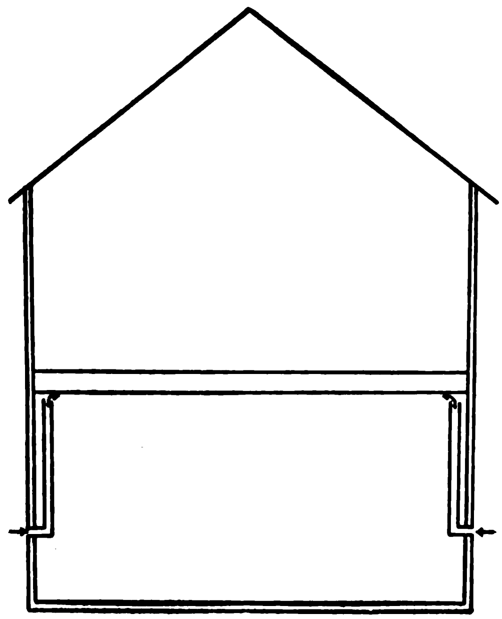


Fig. 308. The construction of the in-take flues in the King system of ventilation.

Wall construction and ventilation.

The principle underlying ventilation is the control of air currents. The circulation both in and out of the building must be through specially constructed flues. It is idle to put the King system of ventilation into a foul-smelling, loosely built barn with a plank floor; it already has too much air circulation in and out. Therefore, the proper construction of the building is the first consideration. The cow stable is the business office and manufacturing plant of the dairyman; it should be as comfortable, in every way, as his living-room in the house. It should be a home for the cows and not a cheerless barn. To accomplish this, the room must be completely insulated from the outside temperature. There is no reason why the best of all side wall construction may not now be advised.

The ceiling, both inside and out, should be of single one-inch matched lumber, leaving an air space between of not less than eight inches. This space should be closely packed with cut straw, or, if this is not convenient, filled with uncut straw. The ceiling should be put on perpendicularly, so that it will not harbor dirt. To insure against the straw being wet by rain, water-proof building paper should be used under the ceiling on the outside. The old way of building a stable of double boards, with paper between, is wrong, because a solid wall will be a good conductor of heat, and hence the stable will always be damp. A single dead-air space in the wall is satisfactory for a few years, but eventually the ceiling will check or a knot will fall out; then the dead-air space is gone, cold air comes in direct contact with the inside ceiling, and condensation follows. The writer therefore advises the straw filling at the outset. This provides, by means of its many air chambers, a nearly perfect insulation. Rats and mice will not be troublesome in this wall if floors are made of concrete.

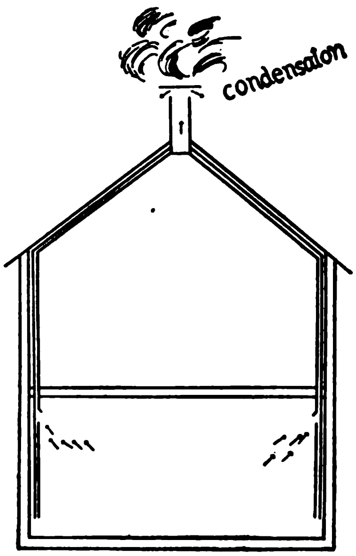


Fig. 310. The construction of ventilating flues. The moisture should condense outside the stable.

A damp atmosphere in the stable is dangerous to the health of the animals and must be avoided. Damp side walls lower the temperature of the stable because of constant evaporation. The expense of the side described above is only a trifle more than the double boards and paper. The ceiling above must also be free from openings. It should be tight, not in the usual sense of barn tightness, but as closely built as a house. If air escapes into the loft, the object of the ventilating system will be defeated and the barn loft will be damp and frosty. Common ceiling should be used and not beaded, as the beading makes crevices to collect dirt. If there are hay chutes, they should be arranged so that the openings may be easily and perfectly closed.

If the builder desires to construct a wall more easily washed with hot water, and more easily kept clean if not washed, a very cheap, efficient and durable surface may be built by lathing over the inside ceiling with ordinary sawed lath, furrowed out one-half inch and plastered with portland cement one part, and white sand two parts. This presents a thoroughly hard and durable wall finish. So-called Keene's cement put on with marble dust or white shore sand will make a wall that will be white without whitewash. This extra coat also more thoroughly insulates the building, all of which is advantageous in securing a perfect working of ventilating flues.

Care should be exercised in arranging the stanchions, box stalls and other fixtures, to distribute the unused spaces over the entire room. In other words, it is well to plan to have animal life distributed through the stable so that the temperatures will be equalized. There should not be an L in which little or no stock is kept; it will have a lower temperature and moisture condensation.

It must not be forgotten that the animal is the source of moisture in the room. The mature cow throws off from lungs and skin about seven pounds of water vapor daily. It is very important that this vapor be not permitted to condense into liquid water until it reaches the outside air through the ventilating flues. This is easily accomplished if the room is insulated and the temperature fairly uniform. It should be realized that in stables we have nothing more or less than a big box stove, the only difference being that the air comes in at the top and escapes at the bottom, while in an ordinary stove it is just the opposite.

Having a stable constructed as just outlined, the builder is now ready to put in dampers and pipes.

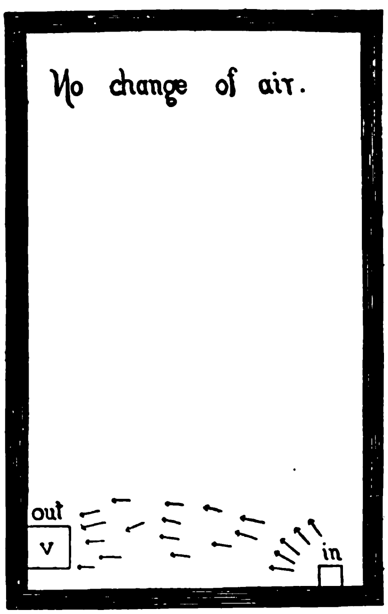


Fig. 311. The wrong way to place ventilating flues.

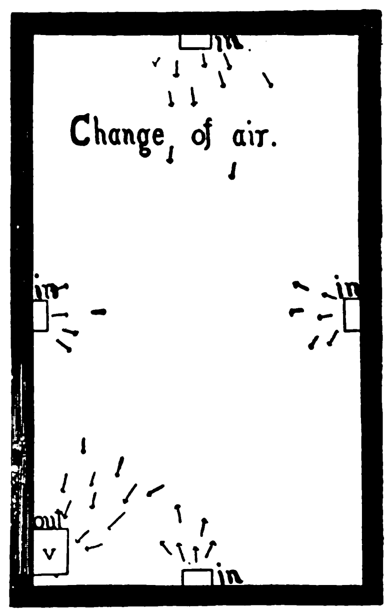


Fig. 312. The correct way to place ventilating flues.

Many a farmer has experienced serious trouble from drippings from a stovepipe that passes through a cold room, or that lies horizontal for some distance or lets into a large chimney where the warm air will cool before reaching the top. The same trouble will follow this ventilation unless the flue is run straight or is insulated against outside cool air. It is therefore safe to build the flue only of matched lumber with paper between the two boards, thus making it vapor-tight. If such a flue is built free from the building and is carried to the highest point of the barn, and projects five or six feet above the ridge, it will always work. The flue is covered with a cap about one foot above the top to keep out rain and to increase the circulation by the passing of strong air currents over the top. These flues must not be built of material that conducts heat readily, as galvanized iron; neither should they be taken out under the eaves or between rafters. They can be built outside the barn, if necessary, in which case insulation must be perfect to

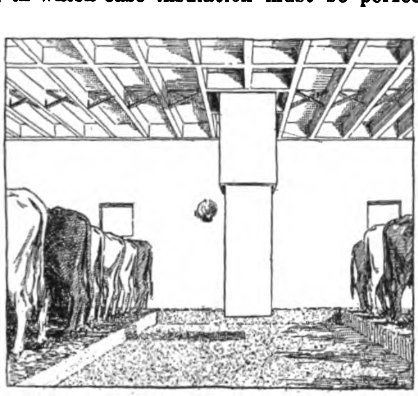


Fig. 313. Interior of a certified milk stable. Note the ventilator in the center. It is so arranged that the lower part can be raised, sliding into the upper. (Hon. C. A. Wieting, Commissioner of Agriculture, New York.)

prevent condensation; probably a double flue, with the air space stuffed with straw, would be sufficient.

The size of the flues should be regulated by the number of animals, and not by the size of the room. A flue one foot square is considered sufficient for five or six cows. For ten cows, the flue should be 1 foot by 2 feet; for twenty cows it should be 2 feet by 2 feet. It is the opinion of the writer, from observation rather than from experience, that one flue located at any convenient place will be as satisfactory as two or more flues for a room holding thirty cows or less. For larger rooms, two flues or more would be better. The writer's experience has been with four flues for sixty animals. (Note Fig. 312.) These flues should open near the floor and also near the ceiling. In each place the opening should equal the full size of the flue. When the temperature outside is low, only the lower opening should be used; when high, the upper should be used. In a room constructed along these lines, it is possible to maintain a constant temperature of 54° to 60° without regard to the outside weather conditions. The stable under consideration (Fig. 303) is located in the coldest section of New York state.

Provision must be made for a constant inflow of cold air. No specific rule can be given for the number of these small flues. The points that must be kept in mind are to have the inflow from all four sides of the room, and through openings not over four inches in diameter, so small that the cold air will become mixed with the warm air before reaching the animals, and also to keep up a constant circulation in the room. In localities where winter temperatures are higher, these flues must be larger. The animals nearest to large openings might be chilled. To illustrate, if the flues were placed as shown in Fig. 311, the air would not be changed over the larger part of the room; but if located as shown in Fig. 312, the change of air would be constant and complete. The manner of constructing the flues is shown in Figs. 308, 309, 310. These flues always work, because cold air entering the stable through them is soon warmed by contact with inside warm air and the animals, and hence rises rapidly. Air will never pass out through these in-take flues. The inflow of cold air, under pressure, materially assists in forcing impure air out through the out-take flues; in fact, each flue assists the other. The writer is unable to give a definite rule as to the number of these small flues, for it depends so much on wind pressure and how much air enters around doors and windows. All doors opening out should be double; when they open into other rooms single doors may answer and may be the means of admitting air to some extent. It is easy to judge whether the volume of air coming into a room is sufficient by observing the course of the air when entering the room. If the circulation is balanced there will be no suction in or out. If the warm air meets one in the face, the out-take flues are not doing their duty; if the air rushes in when one enters, more cold-air flues should be provided. A stable can not be sanitary unless it has been provided with a good system of ventilation. The one outlined here has been very satisfactory. It is the method commonly known as the King system. The health of the cows and the purity of the product demand that ventilation be given

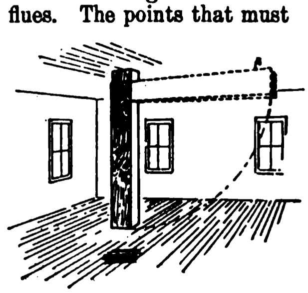


Fig. 314. Movable outlet for air. This tube may be let down on cold nights and hooked up during daytime and in warm weather.

Fig. 315. Protection from dust. Pieces of cloth tacked on half circle to protect harness and other articles from dust.

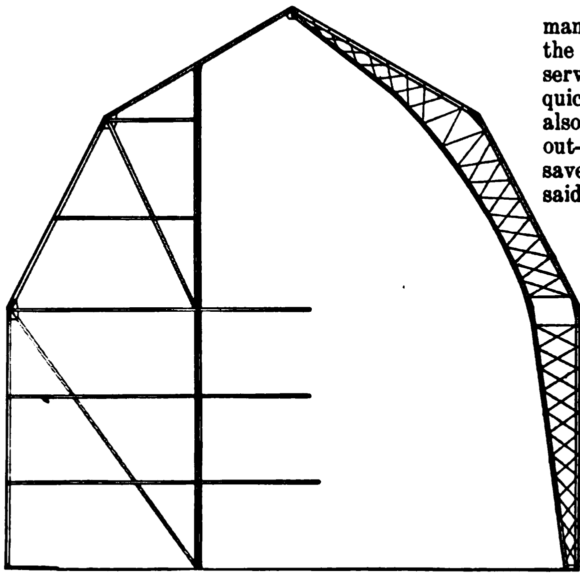


Fig. 316. Truss of steel-frame barn built by F. E. Dawley, Fayetteville, N. Y. Probably the first of its kind in the United States.

careful attention. These special ventilation devices are practicable, and their use is strongly urged. They constitute part of the advance in modern dairying.

Other arrangements.

There is often doubt in the minds of dairymen whether a room over which hay is stored can be used safely for sanitary milk-production. This sentiment is no doubt based on the loose ceiling of former years, from which chaff and dirt were constantly falling. It can have no foundation in fact when the stable ceiling is constructed as herein described. In northern latitudes, living-rooms for cows should be not over 8½ to 9 feet from floor to ceiling. It is therefore necessary to build a floor between the animals and the roof. Why not use this loft for storage, whether it be high or low? A track with car can be placed in the ridge of this loft when it is not convenient to drive above, and hay can be filled in easily and cheaply. If the ceiling is perfectly tight, as it should be, there can be no objection to storing hay or straw above the stable. Only a few of the certified dairies have hay in separate buildings; the dust of hay is, of course, the chief objection. If the hay is thrown down into a narrow room separated from the cow stable by a partition, there can be no good objection to this arrangement.

When the building is narrow, or when it is not considered advisable to drive into the cow room for manure, as is provided for in the stable in Fig. 305, the modern track and carrier are convenient and serviceable; it is well to use one that is easily and quickly raised and lowered for filling. It should also be high enough from the ground when run out-of-doors to dump into a wagon and thereby save one handling of the manure. It should be said that many dairymen prefer this arrangement because considerable dirt is unavoidably brought into the stable when the manure is collected with a wagon. In the writer's personal experience, this objection is more than offset by the convenience of the method. Convenience in feeding makes it essential that the granary, silo and root-storage should be at the most readily accessible point; and stock can be cared for more quickly and more cheaply if all the working parts of the building are on the ground floor. Such construction might entail more barn roof, but the extra expense of this would be fully offset by the lessened labor in caring for the stock.

The outside of the stable.

Eave spouts should always be maintained to prevent an excess of water getting into the wall trench and freezing. If one cares to be economical in the use of paint, one coat of English venetian red, ground in oil, may be applied

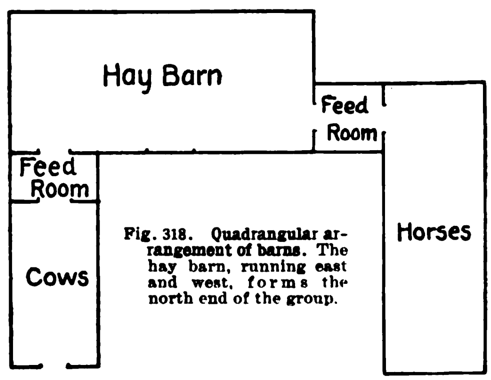


Fig. 318. Quadrangular arrangement of barns. The hay barn, running east and west, forms the north end of the group.

when the building is new, with the cornice painted two coats of white; then in three to five years the operation may be repeated. Or, other colors may be preferred. This will give very good satisfaction to the eye and protection to the building for about fifteen years. Roofing has not been discussed, because the location of the dairy governs the cost and the kind of material to a great extent, and therefore any statements could have no specific application.

These general principles can be recommended unhesitatingly to the man who expects to build a new stable or to improve an old one. The details he can work out according to his own judgment, and the special conditions of his particular case.

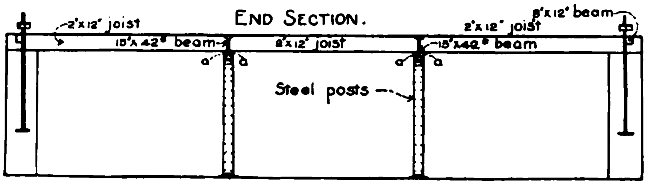


Fig. 317. End section of steel frame of barns of Mr. F. E. Dawley.

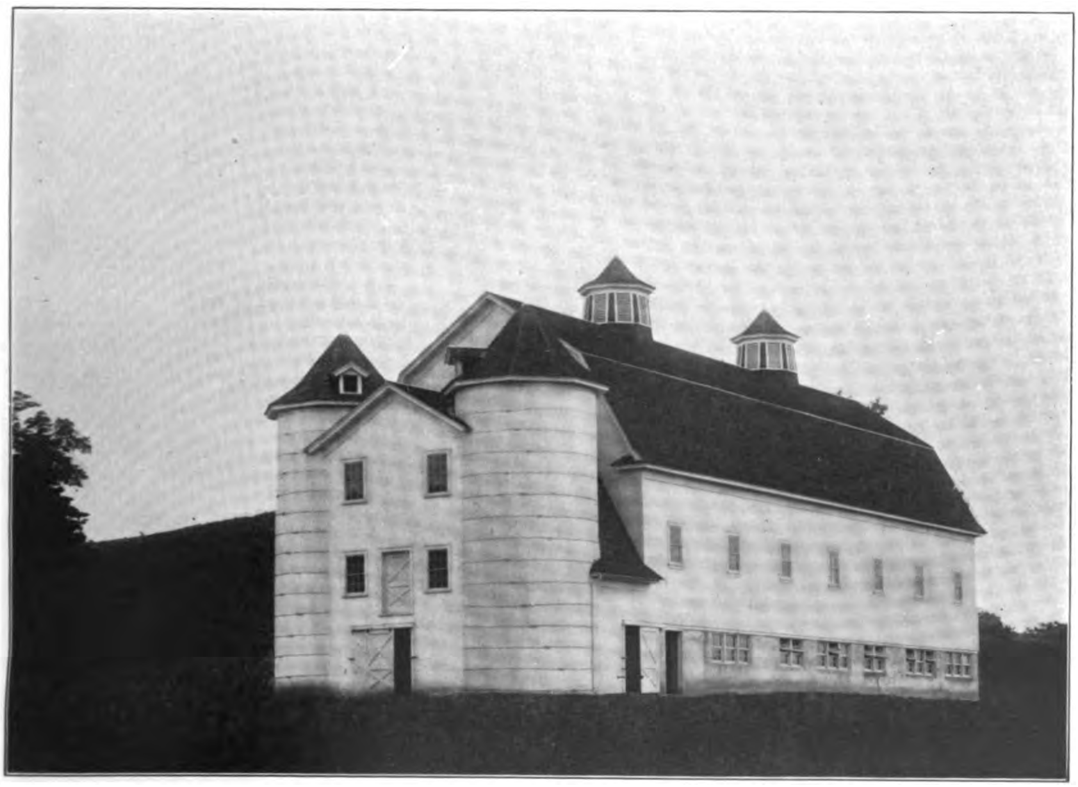


Plate XVI. **An iron-frame trussed barn, said to be the first in America.** The stable part is built of reinforced cement, the only wood being in the doors, window-frames and the front to the ventilators. The barn is sheathed with matched pine. F. E. Dawley, Fayetteville, New York.

Iron frame and concrete construction.

Iron is fast taking the place of wood in structural work. Mr. F. E. Dawley, of Fayetteville, N. Y., has erected a modern sanitary stable, using concrete entirely for the stable, and iron for the framework above. The end truss is partly shown in Figs. 316, 317. The entire space of the barn above the basement is one room. The truss is stronger than the ordinary framework. Each iron girt has a plank attached, to which board siding or sheathing may be fastened. The end sections are braced to the nearest adjoining girt. Wood rafters are fastened in the same manner. In other words, this frame is standard truss or bridge work covered with boards. The cost is somewhat higher than the present cost of wood, but it is only a question of time till builders will be forced to use iron and concrete in farm structural work. The same principles of sanitation, ventilation and insulation are employed, as previously mentioned. Barns are as worthy of good material and careful construction as residences are.

Remodeling old buildings.

This article is chiefly given to the points which should be considered in the construction of new buildings, but with a little study these ideas may be made applicable to buildings now in use. Stuffed walls, matched ceilings, cement floors and ventilating flues may often be introduced to great advantage into buildings now standing. This work may often be done from time to time as means are at hand. It is best to put in the floor first; at another time the flues may be built, and then the ceiling.

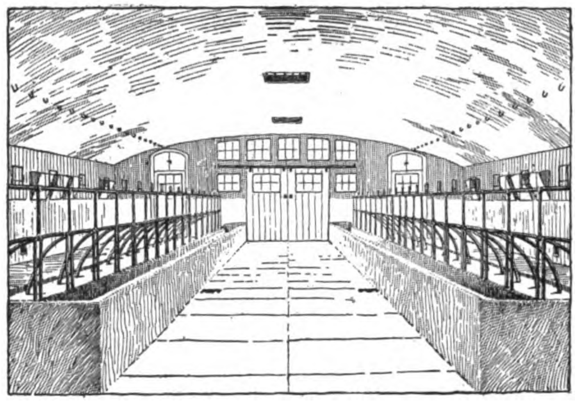


Fig. 320. The concrete trough runs the entire length of the building. The passageway between the double row of stanchions is about eight feet wide. All corners and right angles are finished with coves or in curves, so that dust does not collect or may be easily removed.

The room should never be made tight until the flues are ready for use; a closed room without flues would be exceedingly bad for the animals.

CONSTRUCTION DETAILS OF MODERN BARN AND DAIRY ESTABLISHMENTS

By *E. Burnett*

(With Figs. 318–322, 324, 325, 326, 329, 333, 334)

The usual and most economical practice in the construction of complete barn establishments is to form a quadrangle with the big barn, which contains all the forage and grain, running east and west and forming the north end of the group (Fig. 318). This main building, usually of wood, is built with side trusses 12 to 16 feet apart (Fig. 319). The usual dimensions are 40 to 50 feet in width, 16 to 22 feet in height to the plate, and of such length as will provide for the storage of the necessary forage, allowing 400 to 500 cubic feet for each ton of hay. To this building are usually connected two wings, without cellars or storage rooms above, running north and south. One of these sheds is for the cattle and the other for horses.

Cow and horse stables.

For cattle, when any number are kept, the low buildings should have a double row of stanchions, and should be about 38 feet wide and 7 to 8 feet to the plate, the length being decided by the number of animals housed, allowing 600 to 750 cubic feet of air space for each ani-

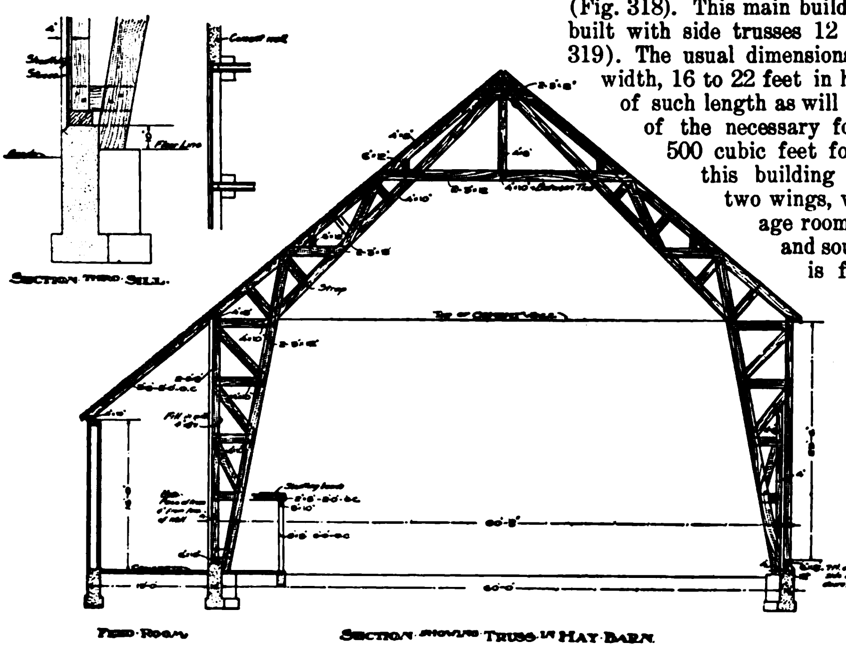


Fig. 319. Section of the main building (hay barn) showing the wooden side trusses. The side trusses are placed twelve to sixteen feet apart.

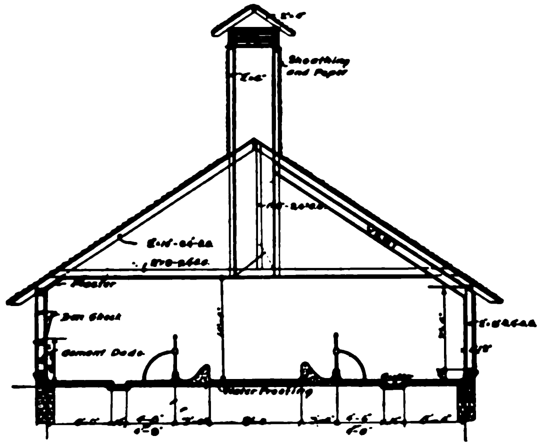


Fig. 321. Vertical section of cow barn. The arrangement of the floor space is liberal and facilitates the work.

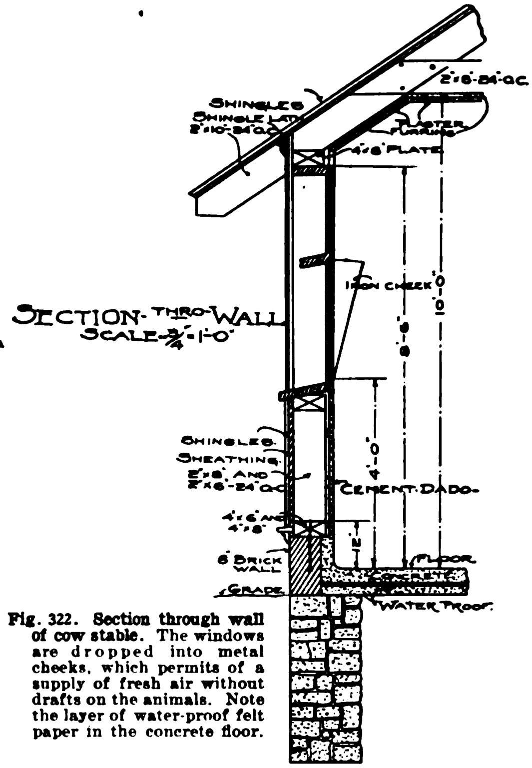


Fig. 322. Section through wall of cow stable. The windows are dropped into metal cheeks, which permits of a supply of fresh air without drafts on the animals. Note the layer of water-proof felt paper in the concrete floor.

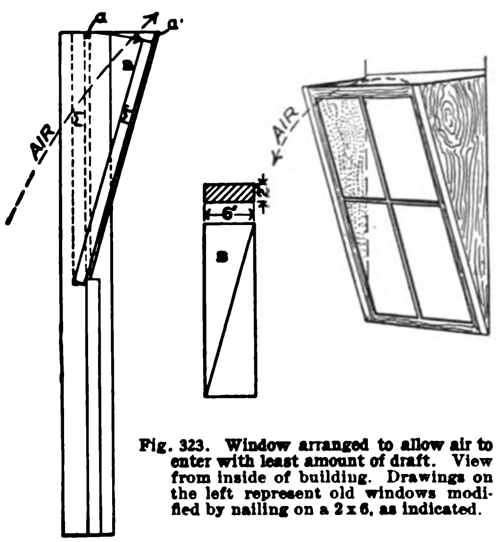


Fig. 323. Window arranged to allow air to enter with least amount of draft. View from inside of building. Drawings on the left represent old windows modified by nailing on a 2 x 6, as indicated.

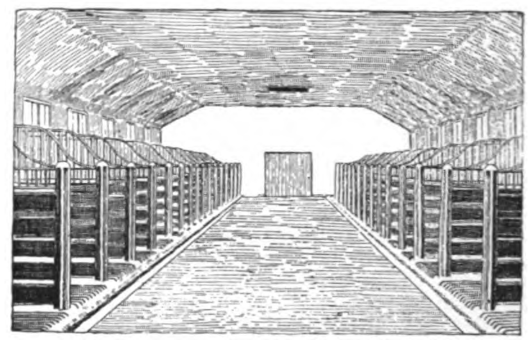


Fig. 324. Interior of horse stable with a row of stalls on either side of a wide passageway. The planks in the partitions are placed about two inches apart, which greatly improves the ventilation of the stall.

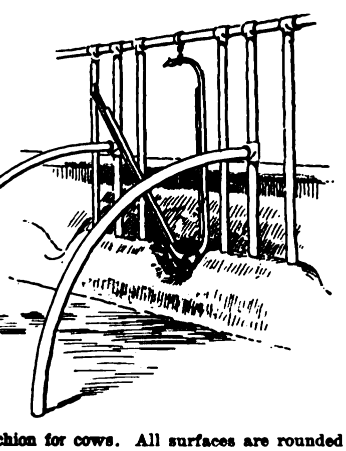


Fig. 325. Stanchion for cows. All surfaces are rounded so that there are no dust-collecting lines.

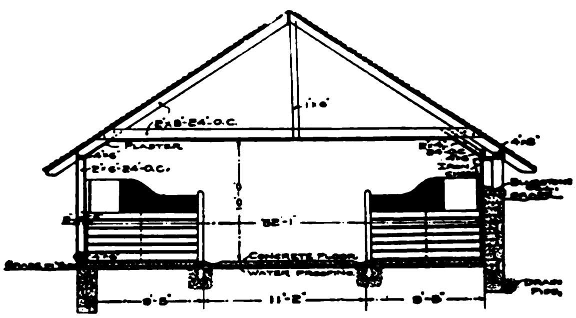


Fig. 326. Vertical section of horse stable, showing the open iron stall ramp above the wooden partition, and the solid panel between the horses' heads.

mal. The interior is finished entirely with concrete floors and base, and the walls and ceiling with portland cement plaster placed on wire lath, in wooden buildings. The sills should be 12 to 15 inches above the floor, resting on a brick or concrete wall, and where this wall connects with the floor there should be a generous curved sanitary base with not less than a 4-inch sweep. The windows (half sash) are placed not less than 4 feet from the floor, and flush on the inside with no casings, so that the whole interior is without any dust-collecting lines. All corners and angles are finished with curves.

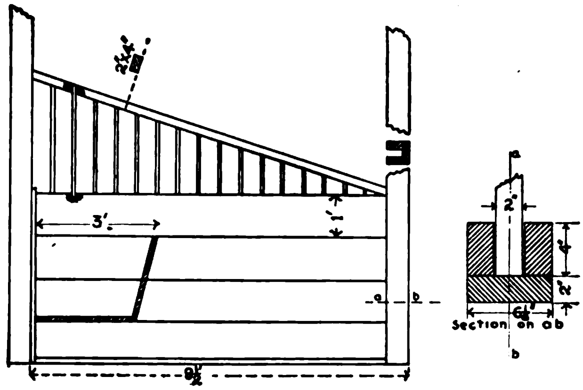


Fig. 327. Partition for horse stalls in a wood-construction stable.

A double row of stalls, allowing 3 feet 6 inches in width for each full-grown cow, faces a passage-way about 8 feet wide. A concrete trough, about 3 feet over all, runs the entire length in front of the stalls, on each side (Fig. 320). This trough provides for both the feed and water. The inflow of water should be from a pipe not less than 2 inches in diameter and the outlet 3 to 4 inches in diameter, so that the trough can be emptied quickly. In horse stables, a concrete watering-trough may be put in some corner; this is better than individual troughs.

The usual length of standing space for an ordinary cow from the trough to the gutter is 4 feet 6 inches. The gutter should be 16 inches wide and about 6 inches deep. In this gutter should be placed a bell trap to provide for the drainage. Behind the gutter, space should be allowed for the rear passage, about 6 feet in width (Fig. 321). The cow stalls are made of 1¼-inch galvanized pipe. The stall-frame set in the inside of the concrete trough is put up to carry metal stanchions. If strap collars are used, the rings and chains to fasten to these collars slide up and down on the uprights.

The installing of the King system of ventilation should allow 28 square inches for each full-grown animal; with twenty cows this requires four outlets and four inlets, 7 x 20 inches or 10 x 14 inches. These outlets should be placed as near the floor as possible, inside the building, and the ventilating ducts from them should extend up through the side of the building, usually between the studding and the roof, to a ventilating cupola not less than five or six feet in height. The intakes are usually placed on the side of the building, the air coming into the ventilating shaft from the outside about one foot above grade, and passing up through the sides of the building to the opening into the interior of the stable just underneath the plate.

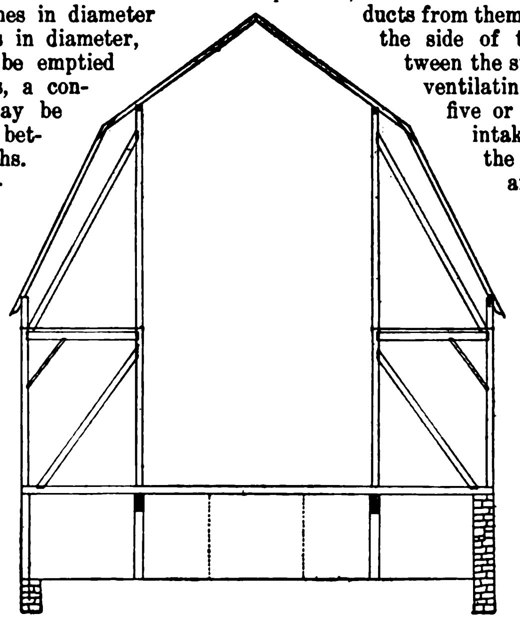


Fig. 328. Method of framing a wooden general-purpose barn. Notice rafters overhanging plate one-fourth their length.

As much light as possible should be provided. By dropping the single sash windows into metal cheeks, fastened to the inside of the window-frame, a liberal supply of fresh air is secured while avoiding drafts on the animals. A rabbet formed on the bottom of the sash and a corresponding cleat on the window-sill does away with hinges, and the sash can be lifted out at any time to be cleaned, or in hot weather entirely removed to provide all the air possible (Fig. 322).

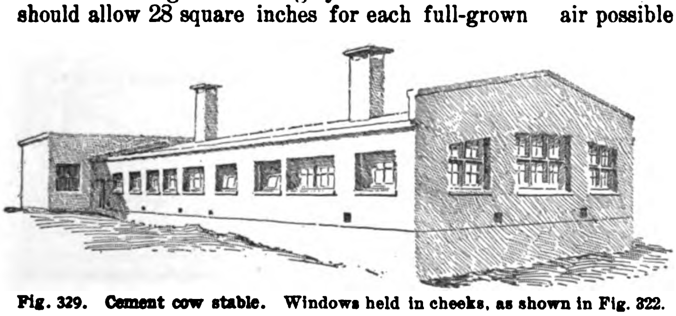


Fig. 329. Cement cow stable. Windows held in cheeks, as shown in Fig. 322.

In the horse stable, the usual custom is to place a single row of stalls on one side of the building, which should not be less than 20 feet in width, or, for a double row of stalls, not less than 30 feet (Fig. 324). The length of the stall is 9 feet 5 inches over all, and the width varies from 5 to 6 feet for a large stall and from 3 feet 8 inches to 4 feet for a narrow stall. The 6-foot stall is the most desirable, as it gives the horse almost the accommodations of a box stall and allows plenty of room for the attendant to harness the animal in the stall. This stable should be finished the same as the cow stable, with concrete floors and base and portland cement plaster on the walls and ceilings. The iron stall posts, 5 inches in diameter, should be embedded in about 20 inches of concrete. The partitions should be made of 2-inch plank about 6 inches wide, placed horizontally and slipping into channels on the post and on the wall. The bottom plank should be placed about 1½ inches from the floor and the others placed 2 inches apart. This greatly improves the ventilation of the stall proper. Above the wooden partition is usually placed an open O. G. iron stall ramp, allowing an open space of 1½ inches next to the wall; then a solid 30-inch panel is usually put in to separate the horses' heads (Fig. 326). The stall floors of concrete are marked with a half-round groove about ¾-inch wide and of equal depth running down the center, with herring-bone side grooves, not so deep, running into this main channel. An open flat gutter with a bell trap is placed directly behind the stalls.

The handling of the manure in modern barns is done by a trolley run on a track suspended from the ceiling in the rear passage. This track is carried through the doors at the end of the building and outside to a point where the bucket is emptied either directly into a cart or into the manure-shed, about 200 feet from the buildings.

The ideal building for domestic animals is made of concrete reinforced with steel. This building is constructed with a 10-inch air space between the two 3-inch side walls, except where abutments are placed to support the concrete beams that form the roof. The roof is built with an air space between the beams, and the interior is plastered directly on the rough walls. The ventilation is easily provided for in the hollow walls, the ducts being formed in concrete. This building with its air space practically obviates sweating in damp weather; it is cool in summer, warm in winter, and is absolutely fireproof.

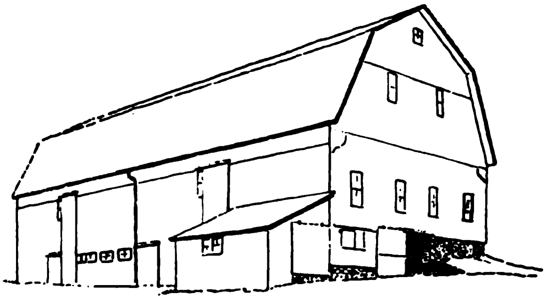


Fig. 330. Barn built on the plan shown in Fig. 328.

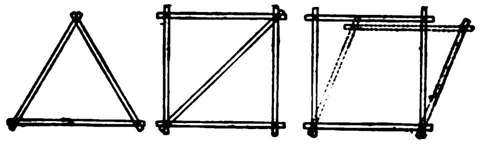


Fig. 331. Trussing. The three sides of a triangle properly fastened to form a good truss.

Fig. 332. Method of trussing roof. Truss is 1 x 8-inch hard wood let into upper surface of rafters and securely nailed to each rafter.

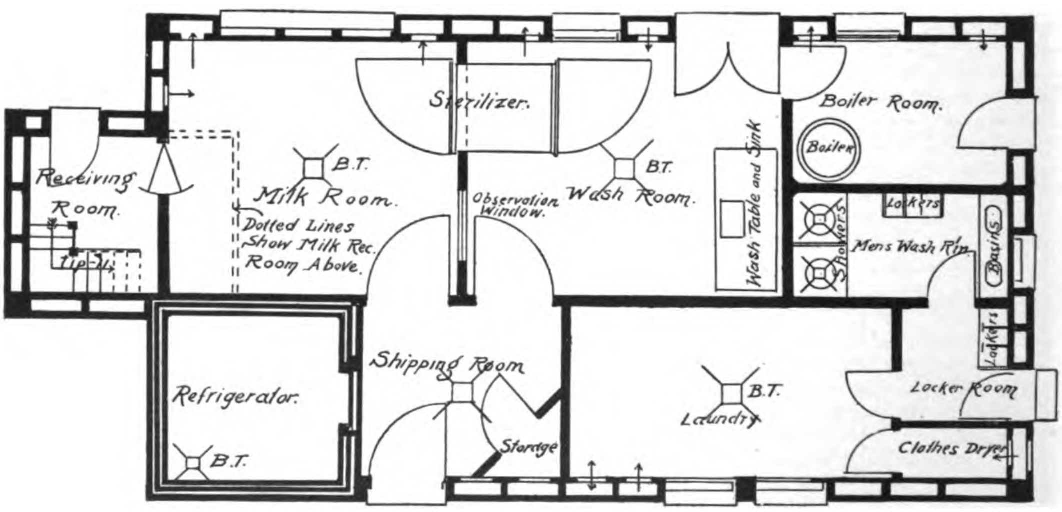
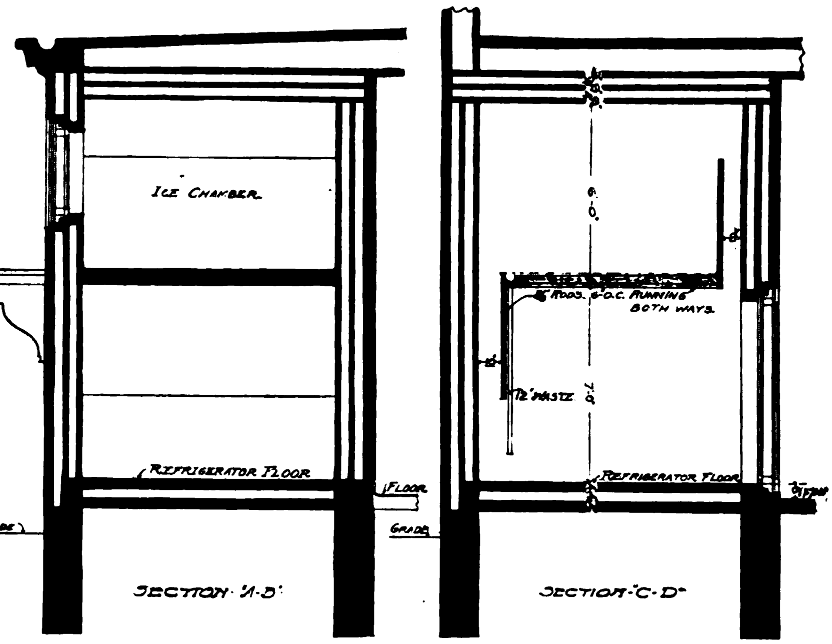


Fig. 333. Plan of dairy-rooms, in a modern structure.

All concrete floors on which animals stand should have a damp proofing of heavy felt paper, laid in with hot tar, between the coarse concrete and the finished floor. This takes off the chill and prevents any dampness coming up from the ground.



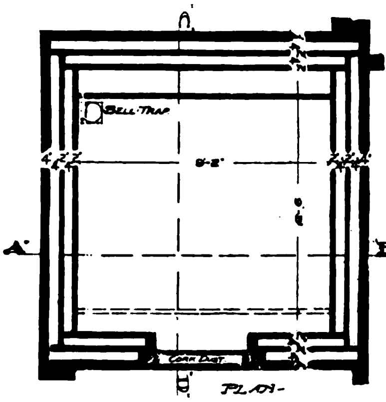


Fig. 334. Sections of refrigerating rooms for a farm dairy.

The dairy.

For a modern dairy building a sunny, well-drained site should be chosen, about 100 feet from the barns and stables, and removed as far as possible from dusty roads, manure piles or other sources of filth. To secure clean milk, the whole process of transferring the milk from the cow to the bottles or cans should be conducted in as cleanly a manner as possible, and the dairy should be arranged to accomplish this. The milk may be transferred from the barns to the dairy by a hand-cart, or, better, because quicker, by means of a carrier running on an overhead trolley wire. A building for handling market milk may be arranged in two divisions: first, a room where the milk is received from the barns and where it is bottled; second, the room to which the bottles are returned by the delivery wagons and where they are washed. The first room contains the milk cooler, the bottling apparatus, and the separator. The milk should come to an upper platform in this room, either by the carrier or hoisted there from the hand-cart. From the upper platform, which should be completely inclosed from the room, the milk is poured through strainers and runs through conductors to the cooler or separator. The cooler of the tubular type is best made of a vertical bank of horizontal tubes through which cold water is kept circulating. This water may be cooled by ice or by artificial refrigeration. The milk, after running over the cooler, is collected in a tank and drawn immediately into bottles. The milk for cream may be run from the platform to the separator, passing over a heater when necessary. The cream may be passed over a cooler similar to but smaller than the milk cooler. If butter is made, there should be a separate room, which may contain the churn, butter-worker, cream tempering vats, print tables, refrigerator and other equipment. (Fig. 333.)

The second room, where the bottles are washed, contains a large sink in two divisions,—the second for the washing soda,—with an apparatus for rinsing the bottles after washing. A rotary brush driven by a steam turbine is an aid in washing. The washed bottles are placed in racks on a truck and run into a sterilizer with two movable heads, one opening into the wash room and the other into the milk room. The bottles may be removed from the sterilizer by opening the door on the milk room end.

In each room of the dairy, besides a cold-water hose-bib, there should be a cross connection to a steam line with a mixing valve, so that steam, hot water or cold water may be drawn from the hose. Refrigerators should be arranged for the milk and cream. (Fig. 334.) These should be kept at a temperature of about 40° Fahr. or lower, either by ice bunkers or brine tanks operated by a refrigerating machine.

The best material for the construction of such a dairy is brick, stone or reënforced concrete, with no wood except sash, doors and frames. It should be plastered inside with portland cement plaster, in any case, and if the building be framed in wood, the plaster should be applied on metal lath. The floors should be concrete. All dust lines should be eliminated by making coves in all the intersections, rounding all edges, and making all doors flush both sides.

Attached to the dairy should be a wash room for the attendants, containing hand-basins, sinks, a shower-bath if possible, and lockers where outside garments may be kept. A steam boiler is a necessity in a dairy; and useful adjuncts are a small laundry where the dairy-suits may be washed, and, if conditions require it, a refrigerating plant for producing the necessary cold in the refrigerators and milk coolers. This refrigerator may be arranged to make ice as well.

OTHER TYPES OF BARN CONSTRUCTION

By *Joseph E. Wing*

The preceding article, by Mr. Burnett, has discussed the modern steel and concrete barn construction. The very apparent utility of such construction leaves no doubt as to the importance it will play in the barn-building of the future. At the same time, there are other types of plank-frame construction that have many features to recommend them.

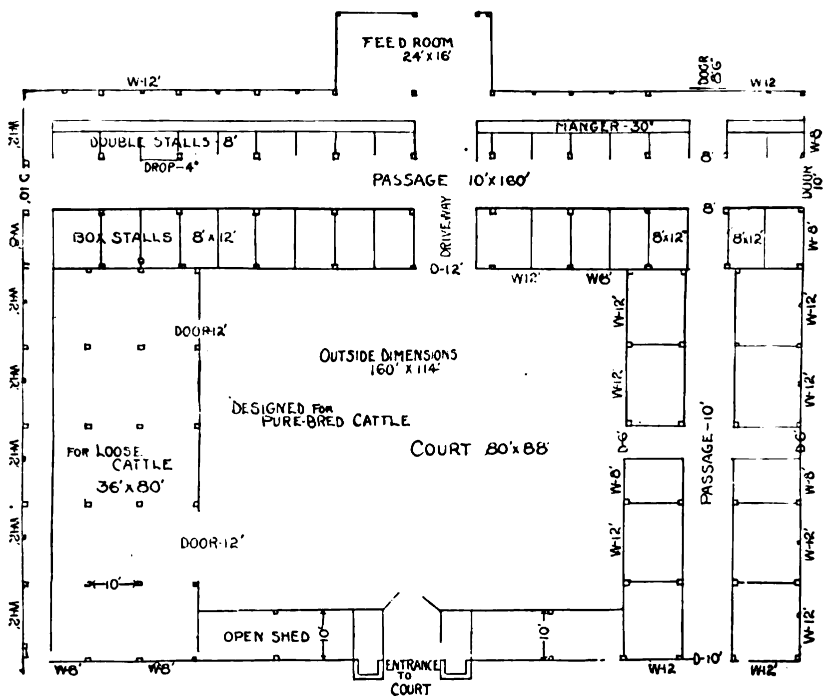


Fig. 335. Floor plan of the Wing stock barn. The wing at the left is open, in which dry cows and young stock run loose. The wing at the right is fitted with box stalls, primarily for bulls.

The wood-frame construction of barns has been a gradual evolution. The heavy hewn timbers used by our forefathers have been hard to supplant. They had much to commend them, and gave a solidity of construction that was comforting. But the increasing scarcity of suitable timber and the demand for a simple construction that could be made quickly and easily have led to the gradual abandonment of the heavy timber framing and the introduction of new types. One of these types was the balloon frame, used alike for house and barn construction. It is not, however, adapted to the large modern barns. The types that have since come in are many and varied according to the notions of the designers, but they are all tending toward some form of simple joist- or plank-framing. The following paragraphs will discuss a few types that are at present in favor among stockmen in certain parts of the country.

The Wing joist-frame.

While the distinctive work of the cattle-grower of the East is dairying, in the Middle West there are numerous herds of cattle of beef breeds, and these require a distinct type of barn. In Fig. 335 is shown a barn designed to hold a herd of Shorthorn cows, with their calves, and young stock. The general arrangement is that of a long, rather narrow building, inclosing three sides of a hollow square, while a shed across the front completes the inclosing of the court. The outside dimensions are 160 x 114 feet, inclosing a paved court 80 x 88 feet.

The plan of the barn in Fig. 335 is very simple. There is one row of cows in double stalls, and behind them a passage 10 feet wide through which a cart or manure-spreader may be driven. On the other side of this passage is a row of box-stalls. Thus each cow may have her calf close behind her, convenient when it may be desired to let it nurse; or any young cattle or calving cows may use these boxes. One wing is composed entirely of a large shed with no partition, in which dry cows or young cattle may run loose, this shed having two large doors communicating with the court. The other wing is more especially for bulls and is fitted entirely with box-stalls, some of which are very roomy. There is a central feed-room and overhead a large storage-room for the hay, which is put into the wings from the ends and into the main barn from a central transverse driveway. All of the floors are paved with concrete. There is a drop of 4 inches behind the cows, and as they are large animals they are given stalls 5 feet long, and some of them even 5 feet 6 inches. There is no gutter or manger. The cows are tied with chains and eat from the floor of the feed passage, though there are partitions to prevent the stealing of each other's food.

The inner court affords shelter and sun during winter days. An almost continuous line of windows, of one sash, as high as the space will permit, hinged at the lower edge and opening inwardly, admit the air over the cows; and with the aid of air-shafts through the loft, the air is easily kept pure and fresh. There is not the same need of warmth with beef cattle that there is with the dairy breeds, their body-fat keeping them warm; and they keep in better health when they have an abundance of fresh air. In fact, it is better for the cows to be out-of-doors as much of the time as possible without undue exposure. Tuberculosis is to be guarded against in the beef breeds as well as in the dairy breeds.

This structure is in what is called joist-construction, there being no plank more than two inches thick. This form of construction is far more rapid than the old-fashioned framing of square timbers, is stronger, cheaper and in many ways it is better. A cross-section of the frame is shown in Fig. 336, and an elevation of part of the side in Fig. 337. The self-supporting roof is in the form of an arch and is very strong. At the peak is hung a steel track with carrier that takes up the largest loads of hay in two or three hitches and carries it to any part of the mow.

The Kassens rib-frame.

In this construction the foundations are concrete, channeled or dished on the upper surface to make concrete feed-troughs, the rim of the trough supporting the superstructure. Fig. 338. The frame is made of two-inch plank, 4 to 12 inches wide. These timbers are placed singly, avoiding, whenever possible, the building of beams, posts,

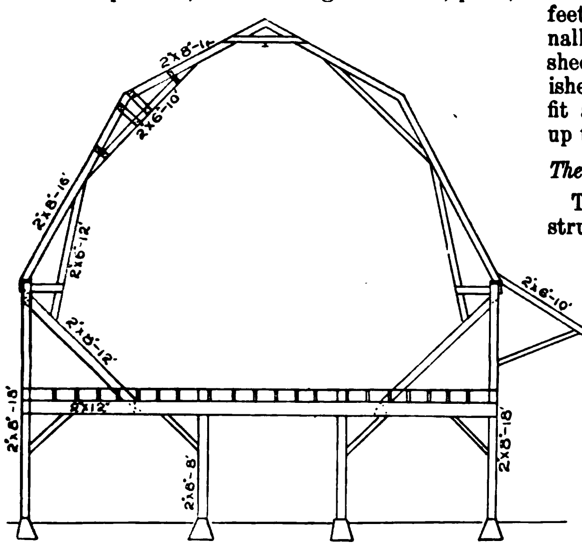


Fig. 336. Cross-section of the Wing joist-frame barn construction. The roof is self-supporting and the interior is open.

plates and the like. The burden of the building and contents is distributed evenly over the foundation, and every timber in the frame is made to carry its share of the load. Since the weight is not collected, beams and posts are unnecessary. The ribs are usually made of 2 x 6-inch timber. The loft-floor joists, which act as cords to bind the sides together, are of a size estimated to be suffi-

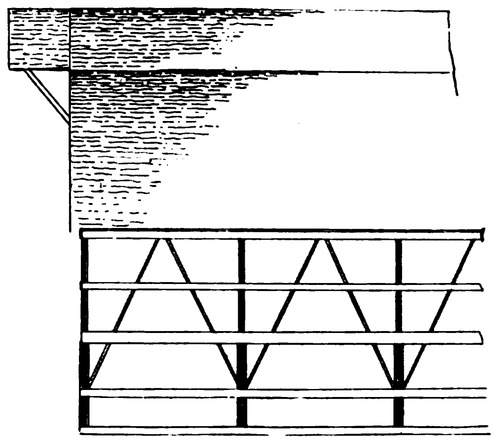


Fig. 337. Elevation of a part of the side and roof of the Wing joist-frame barn construction.

cient to sustain the load likely to be placed on them. The loft space is unobstructed. Feed is taken in at the ends on an overhead track, through doors hinged at the top and opening outward and upward.

To put up this frame, a rib, which includes the side studding, intermediate studding, rafters, splices and braces, collar beam and loft-floor joist, is spiked together on the ground and raised with a derrick. The several ribs are usually placed two feet apart on centers, and after bracing longitudinally the siding is put on horizontally, the rafters sheeted, the building roofed and the interior finished as required. The rib-frame can be made to fit any kind of ground plan and span any width up to fifty feet.

The Shawver plank-frame construction.

The pioneer in joist- or plank-frame barn construction was the Shawver frame, named from its inventor, Mr. John L. Shawver. This frame is shown in Fig. 339. No plank of more than 2-inch thickness is used, except perhaps in the basement, where square timbers may be employed. The basement posts, unless square timbers are used, are made of five 2 x 8-inch planks. The sills consist of two 2 x 8-inch planks, separated by a 2-inch space. The girders or supports to carry the joists, which extend across the long dimension of the barn, are made of three 2 x 10-inch planks. The purlin plates and the posts that support the roof-truss are made of two 2 x 8-inch or 2 x 10-inch plank (depending on the length of the span), placed two inches apart. The main plates consist of two 2 x 8-inch planks nailed together at an angle, inverted over the upper end of the posts and capped by a 2 x 10 or 1 x 10 cap plate with which joints are broken.

The stays, braces and sub-ties are made of smaller stuff, 2 x 4-inch and 2 x 6-inch. The main ties are of single 2 x 8-inch plank.

The braces extend from the basement up between the sills, and tie the superstructure and basement

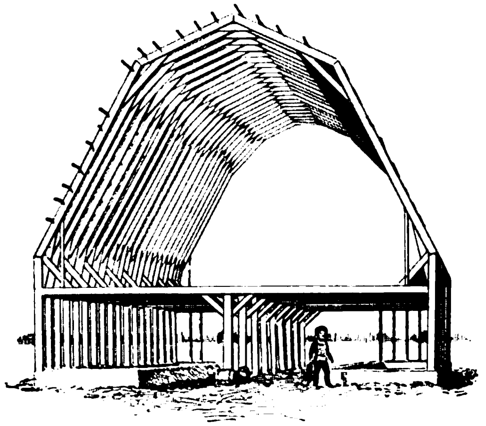


Fig. 338. Skeleton of the Kassens rib-frame.

into one strong frame. The end braces of the basement enter the sill of the basement as well as the sill of the superstructure. At each bent or section of the frame a truss is raised, extending to the peak of the roof and across the barn. On this truss are erected the plates, purline plates, nail girts, and afterward the rafters above the truss. The bents must be built perfectly square. The stiffeners are secured to the inner plank of the post before the post is secured to the bent, using No. 60 spikes. The purline plates are usually placed so that the space between the plates and the purline is three-fifths of the total distance from plate to comb or peak, or nearly so. The bents are all made on the ground before any are erected. The plates are made in sections on the ground, and when the cap plates are put on the joints are broken.

The construction is adapted to any style of roof — gable, gambrel, hip or other — and the roof is

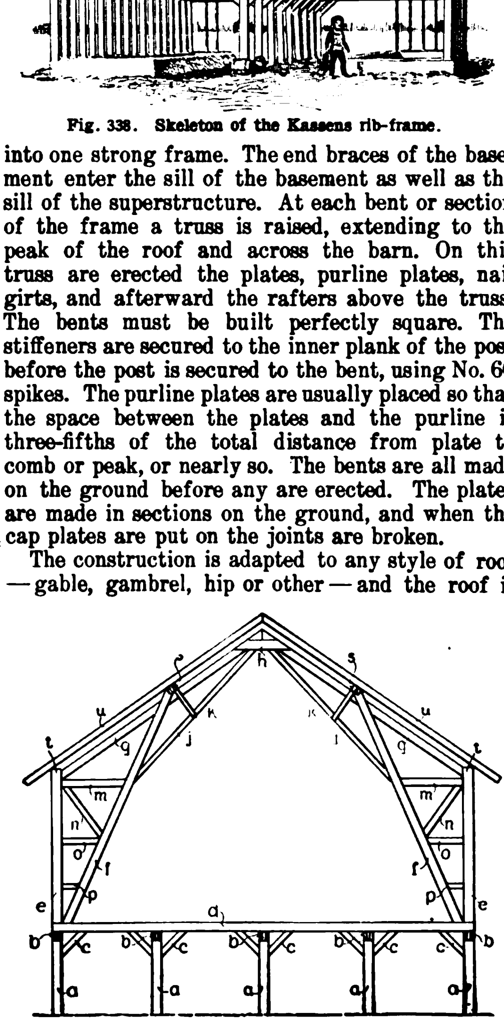


Fig. 339. Interior bent of plain gable barn, with basement, Shawver plank-frame construction. *a*, post of basement; *b*, girders; *c*, braces; *d*, sill of superstructure; *e*, post; *f*, purlin post; *g*, roof support; *h*, collar beams; *j*, sub-support; *k*, stay; *m*, main tie; *n*, brace; *o*, tie; *p*, tie; *s*, purlin plate; *t*, main plate; *u*, rafter.

entirely self-supporting. There are no beams and braces in the interior to catch dust and interfere with the handling of hay. This frame is immensely strong, each piece being placed where it adds most to the efficiency of the whole, and it is convenient of use.

Whatever type of frame is chosen, it should be well put together, the joinings made secure by the use of sufficient spikes and bolts to insure its never parting; and the building should always be set up from the ground on concrete or stone piers sufficiently high so that the moisture cannot affect the bottoms of the posts. It is well also to place flat on the concrete block or stone a piece of 2-inch plank of some durable timber, on which the posts will rest; this will effectually stop the entrance of moisture, and, should it decay, it is easily replaced. Very many of these frames are in use and their strength and suitability have been abundantly proved.

THE MODERN HOGHOUSE

By *William Dietrich*

Probably nothing is more eloquent of the contemporaneous advance along agricultural lines than the new ideas that are now working themselves into hoghouses. Hogs will live anywhere. "As dirty as a pigpen" has become one of the common phrases. Yet hogs respond as well as other animals to good care. They do not thrive because they are kept unclean, but in spite of it. The principles of good building construction are now applied to quarters for swine, and these quarters become attractive and dignified, and worthy of a profitable business. It is worth while to discuss hoghouses at some length, if for no other reason than to mark the change in agricultural ideals.

Location of a hoghouse.

The proper location of a hoghouse, or of quarters of any kind for the shelter of swine, is one of the first essentials to success in swine husbandry. Surroundings should be as near to nature as the improved condition of the animals and circumstances of the owner will permit. Swine in the wild state inhabit the forest where there is shade, water, protection from cold winds, and where the drainage is such as to allow the animal to choose his conditions to fit the season. Ideal surroundings for swine are those that will satisfy their natural desires, together with such modifications and improvements as conduce to financial profit.

The best location for a hoghouse is one that is well drained and well lighted, and that gives access to good shade and a stream of pure running water, and where there are opportunities for making wallows in clean mud. A sandy, gravelly or stony soil is preferable to a clay, silt or muck soil. An ideal disposition, in the judgment of the writer, is to have the hoghouse on a rolling pasture where there are plenty of shade trees, and to have a stream of pure water flowing through the pasture not very far distant. The ravine or valley through which the stream flows should have some mud bottoms in shady places.

A gravelly or stony soil is best, because it is the nature of hogs to root, and a great deal of food is obtained from the soil in the form of plants, worms and insects, as well as many materials that are not foods but are necessary to the health of swine. A rolling pasture is preferable, because it furnishes better drainage; and by causing the animals to travel up and down the grades it develops a great deal of muscle, so much relished by all consumers of pork. Strong legs with upright pasterns, which are the first essentials of a good hog from the breeder's standpoint, are more easily developed in this than in any other way.

A good stream of running water is necessary, for then drinking-water in the purest form will be available at all times and it will be more wholesome than if it is supplied in a trough, where it is bound to become more or less warm, stagnant and foul. A mud wallow is enjoyed more by swine in

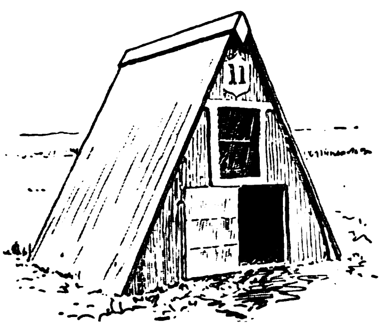


Fig. 340. Lovejoy portable farrowing house. This house may be moved with but little trouble; it is built on skids and may be drawn by a horse.

summer than any other one condition that may be furnished them. It keeps the animals cool, destroys lice and maintains the skin in a good, healthy condition.

Kinds of hoghouses.

As to the kinds of hoghouses that are best there is, among breeders, a wide difference of opinion, and it is very natural that it should be so. A hoghouse that is best for one set of conditions and methods of handling swine may not be best for another. This difference is due largely to the originality of the different breeders who have solved the problem to suit their convenience. The two general classes of hoghouses most in use are the individual house, and the large house with individual pens.

The individual hoghouse, or cot as it is sometimes called, is built in many styles. Some have four upright walls with a roof sloping one way, all of which, the walls and roof, are in separate pieces so that they can be taken down and be easily replaced, making the moving of the small houses or cots an easy matter. Others are built with two sides sloping in toward the top so as to form the roof, as in Figs. 277 and 340. These may be built on skids and moved as a whole by drawing with a horse. There are many other forms, varying almost with the number of individuals owning them. The form in which these houses are built is of little significance so long as the general principles pertaining to the health of the animals and the convenience of

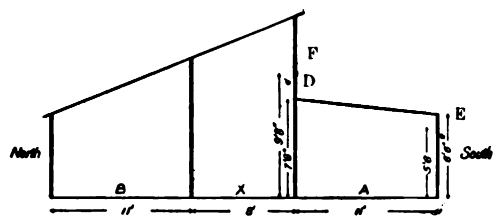


Fig. 341. End elevation of a hoghouse designed to admit the direct rays of the sun to the floor of all the pens, to be well-ventilated, and to exclude the hot sun during the summer. (For 40° north latitude.) Note the height of the windows at D and E. (See Fig. 342.)

the breeder are observed. The houses should be built and located so that they will admit sunlight in winter, exclude cold drafts, furnish dry sleeping quarters, and be as convenient as possible under the circumstances.

The points in favor of individual houses for swine are: each sow at farrowing time may be kept alone and away from all disturbance; each litter of pigs may be kept and fed by itself, insuring that there will not be too large a number of pigs in a common lot; the houses may be placed in pastures and moved as necessary, and they may be placed at the farther end of the feed lot, thus compelling the sow and pigs to take exercise, especially in winter, when they come to the feed-trough at the front end of the lot.

Large hoghouses also have some points of advantage, if properly built: They are sanitary, serviceable, and economical as to labor required in caring for the swine.

Sanitation.

In order to be sanitary, a hoghouse should admit the direct rays of the sun to the floor of all the pens, not allow cold drafts in winter, be well ventilated, and exclude the hot sun in the summer. Fig. 341 shows the end elevation of a hoghouse built

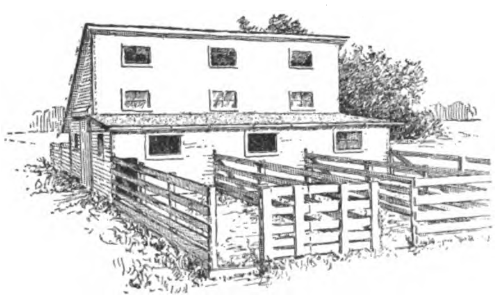


Fig. 342. Exterior view of a section of the hoghouse at the Illinois Experiment Station, showing low flat roof on south side of building and the placing of windows and ventilators.

with these points in view. The building as a whole is 30 feet wide, with an 8-foot alley running lengthwise through the center, represented by X in the figure. The pens are represented by A and B.

The important factor to consider in this connection is the height of the windows, represented at E and D, in connection with the width and manner of construction of the building. The upper part of the window, E, is placed 5 feet 6 inches above the floor. With this arrangement of window for the pen on the south side, the ray of light that passes through the upper part of the window in the shortest day of the year, namely about December 21, and at noon when the sun is at its highest point during the day, in the latitude of Urbana, Illinois (about 40° north), will strike the floor of the pen on the opposite side from the window, thus allowing the total amount of light coming through the window at this season of the year and time of day to fall on the floor within the pen. In the morning and in the afternoon when the sun is not at its highest point, this beam of light will pass beyond the pen; but as the sun rises in its course, as the days grow longer, there will be more and more direct light from the sun on the floor of the pen. Consequently, in the winter months there will be a maximum amount of sunlight falling on the floor. The window, D, in the upright part, which is on the south side of the alley, performs a similar function for the pen, B, on the north side of the alley.

By this arrangement of windows, insuring a maximum amount of sunlight on the floor in the shortest days of winter, the interior of the hoghouse and especially the beds will be warm and dry, thus making it possible to have pigs farrowed very early in the season. Moreover, sunlight not only warms and dries the building, but destroys disease germs, thus making the building both comfortable and sanitary. This is further augmented by the window, F, which acts as a ventilator. It is hung with hinges at the top and supplied with a cord over pulleys, so that it can be opened and closed at will by the attendant standing on the floor of the alley. Furthermore, this building will not admit the rays of direct sunlight to the pens during the hot part of the day in summer, making it a comfortable place for the sows to farrow in August. To secure this arrangement of windows in the latitude above cited, it is necessary to have the top of the window on the south side 5 feet 6 inches from the floor and the top of the window which throws the light into the pen on the north side 9 feet 8 inches from the floor. This necessitates a flat roof for the part of the building south of the alley, which must necessarily be made of some material that will shed water at a slight pitch. The wall on the north side is made as high as that on the south side, but the roof on the north side and alley is made steeper to provide more air space and good ventilation. This part of the roof may be covered with shingles. Structurally, the weakest part of the building is where the flat roof joins the upright, for this place will leak unless extra care is taken in the construction.

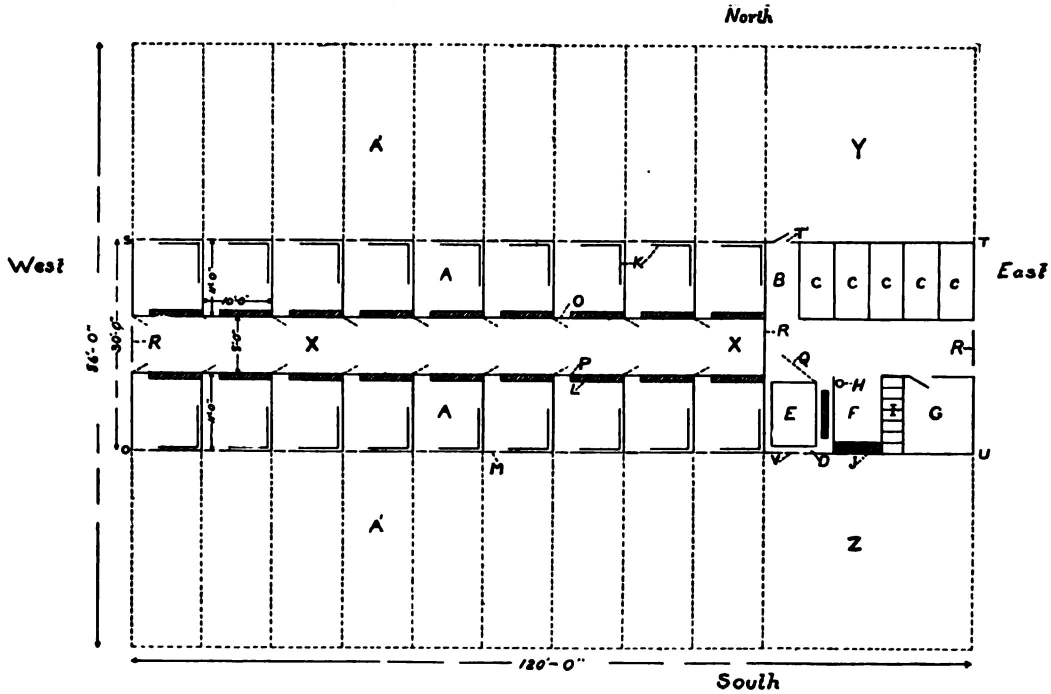


Fig. 343. Ground plan of a hoghouse built at the Illinois Experiment Station. It is arranged to economize labor. The long dimension of the house is east and west, permitting the sun to enter the side of the building. (See also Figs. 341 and 342.)

Serviceability.

In order to be serviceable to the utmost, a hoghouse should be constructed so that it can be used every day in the year. To be an economizer of labor, the house should be planned so that the largest amount of work may be performed by a single attendant. This, in the present day of scarcity of labor, is a very important factor. Fig. 343 shows the ground plan of a hoghouse, a part of which was built at the Illinois Experiment Station in the season of 1904; the remainder is being built at the present time (fall of 1905). The ground plan of the complete structure, which is 120 feet long by 30 feet wide, is represented in Fig. 343, by O, S, T, U. The long dimension of the hoghouse is east and west, thus permitting the sun to enter the side of the building as already described. The alley, X, which runs lengthwise through the center of the building, is 8 feet wide. This permits of driving through with a wagon, which allows the feed and bedding to be hauled into the building where it is needed and the manure to be loaded on the wagon directly from the pens and hauled to the fields. By this means it is possible to perform a maximum amount of work with a minimum amount of labor.

The pens A are 10 feet wide and 11 feet deep. Each pen has a doorway leading to the outside, which is closed by a door sliding upward. There is also a door opening into the alley on the inside. This door is hung so that when it is open it will turn the pigs toward the front end of the hoghouse, where they are to be weighed. It also permits of changing pigs from any pen to any other pen, and of easy access for the attendant to the pen. The trough, L, is placed on the side of the pen next to the alley, and with the arrangement of a swinging panel above this trough, as is shown in Fig. 344, makes feeding a very easy and convenient operation. The fender in the pen is shown by K in Fig. 343. This is made of 2-inch tubular iron placed on iron posts of the same size, set in concrete in the floor. This fender is placed 8 or 9 inches above the floor and about 6 inches from the wall, and is to prevent the sows from lying on the pigs at farrowing time. The sow will necessarily make her bed in this corner, as all the other three corners are occupied, two of which have doors and the other the feed-trough. In the scale room, D, Fig. 343, is placed a platform scale, E, on which the pigs are to be weighed as desired. This platform scale has a frame on it, and the door on the side next to the alley opens as shown at Q, so that when the pigs come down the alley they will necessarily have to walk on the scales. At the other side of the scale platform is a smaller door in the frame which opens through a door, V, of the building, thus allowing the pigs to pass from the scale room directly to the outside, where there may be a chute leading to a wagon, in case they are to be loaded and taken to market. In experimental feeding the pigs may be driven to the scale, weighed and again returned to the pens, with very little work or trouble. The feed-mixing room is represented by F, in which is a table, J, and small feed-bins, I, for feeds of various kinds. From the hydrant, H, water is drawn for mixing slops, and the hose is attached to it to sprinkle the floors; from it also water is furnished in the troughs to the pigs after they have finished eating. Separate water-troughs are supplied in the pens on the outside of the building. The letter G shows the office, and C the feed-bins in which is stored the feed as it is hauled to the hoghouse. The opening to these feed-bins is from the main alley of the hoghouse, from which the feed is put into the bins directly from the wagon; it is taken out in smaller quantities and put into the small bins in the feed-mixing room, from which it is weighed out to the pigs at feeding time. By B is shown an alley which leads through the door, T′, to the yard, Y, on the outside. Opposite this is the yard Z. These two yards are not connected with pens on the inside of the building and are used as boar pens, and are supplied with separate cots and feed-troughs on the outside. The remainder of the pens on the outside, shown as A′, are the same

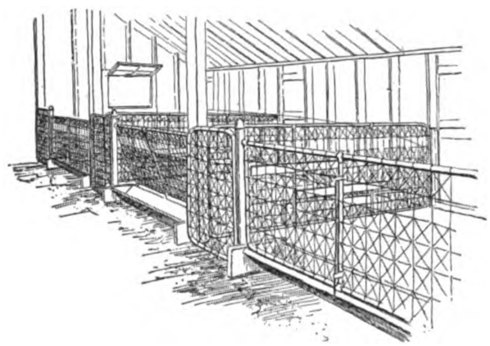


Fig. 344. Interior of the hoghouse built at the Illinois Experiment Station. All gates and partitions are made of iron. Note the swinging panel about the trough in the central pen.

width as the pens inside and are 28 feet long. They are connected with the pens on the inside by means of the doors above mentioned, the outer end opening to the lane which leads to the pastures. The partitions between these pens on the outside are made of two lengths of common fencing, one 16 feet and the other 12 feet long. The 12-foot length is next to the building and made into a gate so that it will swing. By opening all these gates and swinging them one way, and away from the building, it makes an alley along the outside of the building that can be used in case it is not desirable to use the alley in the building for taking out the manure, but this is not so convenient as driving through the alley on the inside.

In Fig. 344 is shown the interior of the north side of the section of hoghouse represented in Fig. 342. All the gates and partitions on the interior are made of wire-netting panels. Wire is considered better for this purpose than lumber, for several reasons, as follows: (1) There are no obstructions to light. The rays of light coming through the windows are not prevented from reaching the floor, where they are most needed; they keep the floor or bed in which the pigs sleep dry, warm and disinfected. (2) By this means there is not the opportunity for disease germs to lodge in cracks and crevices or in the shadow of solid fences; and in case the hoghouse should ever become infected with communicable disease it can be much more easily and thoroughly disinfected. (3) The hogs are kept within sight of each other and of the attendant. By this means the sows, when they are shut

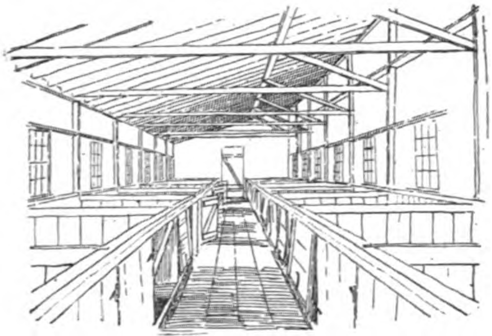


Fig. 345. A good wooden hoghouse.

up to farrow, will not become estranged from one another, and will not be so likely to fight after returning to a common pasture. The argument in favor of the individual houses is that hogs are kept away from each other so that they can not fight; but in this kind of a large hoghouse they can be kept together, thus necessitating fewer pastures and allowing the general farmer to utilize all his fields as hog pastures at different seasons of the year or in different years, and at the same time preventing the fighting. The hogs may be allowed to go in a drove from the hoghouse to any field on the farm, and with very little training each sow with her litter will return to her own pen at night.

An objection has been urged against the large hoghouse to the effect that, by having a large number of brood-sows in such close proximity to each other, if one is disturbed all will jump up, and when feeding is begun at one end all the others will become uneasy and perhaps injure the litters. This objection may hold when the partitions are solid board fences, but by the arrangement herein described the sows can see each other and know what is going on about them, and, not being strange to each other nor the attendant, will not be disturbed. If the feeding is done regularly and in the same order each day, the sows or pigs soon become accustomed to the system and wait patiently for their turn. Furthermore, by this arrangement of wire partitions the little pigs are more easily tamed and will do better beeause they will not become frightened every time a person passes the pen.

The floor of the hoghouse is made of hard brick, laid on side in the pens and laid on edge in the alley. Lumber is not used, because, being necessarily laid on the ground to prevent cold air or cold drafts getting beneath the floor, it will rot out quickly, making it very expensive. Brick is used rather than cement, because it is thought to be a little warmer in winter and not so slippery. Brick is colder in winter than lumber, but this can be obviated by using bedding or by making a portable floor of one-inch lumber for the corner of the pen where the bed is. Fig. 342 shows the exterior of the section of the hoghouse that has already been built.

Accessibility to pasture.

The third general characteristic of a successful hoghouse is that it should be accessible to pasture. Fig. 347 shows an arrangement by which this can be accomplished. In this cut B represents the hoghouse, A′ the small pens on the outside adjacent to the pens on the inside, and Y, the boar pens mentioned above. By L is shown a small pasture that may be used for a boar or any other hog or pigs. The lane by which the hoghouse is approached is at D; E and F are lanes leading from each side of the hoghouse to the pastures. The pastures for the hogs that have access to the north side of the building are shown by H, and by J the pastures for those on the south side. This arrangement is only suggestive, and may be modified to suit the location or the fancy of the builder.

Operation of large hoghouse.

The large hoghouse is planned to supply the needs of the man who raises hogs for the general market as well as the one who produces high-class breeding stock. It will permit of producing two litters per year from the same sows. This, it is very often said, can not be done successfully. But the cow, the mare, and many other animals will support one young at the udder and at the same time the embryo of another within the uterus. The sow can produce two litters per year and never be supporting more than one at the same time.

The sows are bred to farrow in February. During the winter, in order to get exercise they are allowed to run on a pasture or in a barnyard and to come to the hoghouse to get their feed both night

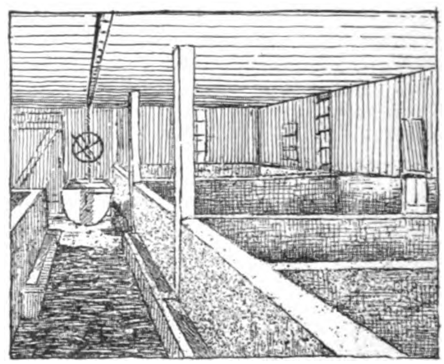


Fig. 346. Pigpens of cement construction. Note the manure-carrier. (H. E. Cook)

and morning. Each sow is trained to come to her own pen; this can be done with very little trouble. About a week before farrowing time each sow is confined in her pen, having access, of course, to the small yard on the outside. She is kept here till the pigs are one to two weeks old; by this time they have learned to know their mother so that all can go to pasture. The sows and their litters are then fed in their respective pens each morning and evening till weaning time. At this time the sows are taken to a pasture on the outside and bred for the second litter, which is to be farrowed in August. After weaning and up to this time the sows are kept away from the hoghouse in a pasture and the pigs are fed, each litter in its respective pen, in the hoghouse, having access, of course, to pasture during the day. This is the growing period for the pigs, and for the best results it is necessary to feed them under conditions such that the feed can be controlled. When it is time for the sows to farrow again they are returned to the hoghouse and the pigs are taken out to a separate lot and finished for market. At this time the pigs ought to be put on full feed and may be fed in larger droves. This process is repeated twice each year, but in winter when the weather is cold a few pens at one end of the hoghouse or a separate shed on the outside must be reserved for the brood-sows and later for the fattening hogs.

A hoghouse built and operated according to the above plan not only furnishes the conditions that are used as arguments in favor of the individual house, but also makes possible a number of conditions that it would be impossible to secure to so perfect a degree in the individual house. Among these are better sanitation, greater ease in handling hogs, thus permitting of the greatest amount of work with the smallest amount of labor, and permitting of fewer and larger pastures, which involves less expense for fences. Besides this, the pigs can be marketed at seasons of the year that are out of the ordinary.

For further information the reader should consult Bulletin No. 109, Illinois Experiment Station, Urbana, Illinois; Swine, by George E. Day, Guelph, Ontario; Farm Buildings, by the Sanders Publishing Company, Chicago; Swine Husbandry, by F. D. Coburn, published by Orange Judd Company; Harris on the Pig, by Joseph Harris, published by Orange Judd Company; Modern Farm Buildings, by W. Clarke, published by B. T. Batesford, 94 High Holburn, London.

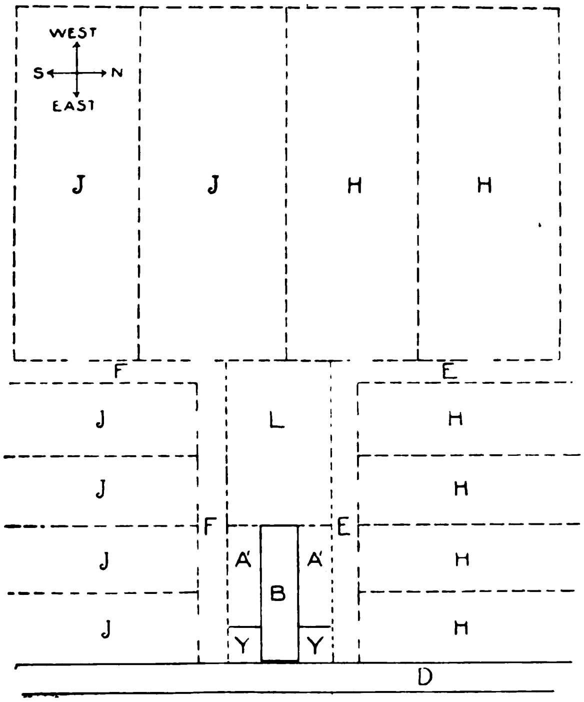


Fig. 347. Diagram showing the relation of hoghouse to pastures. B, hoghouse; A', small pens; Y, boar pens; L, small extra pasture; E, F, lanes; H, J, pastures; D, lane to hoghouse.

FARM COLD-STORAGE BUILDINGS

By *G. Harold Powell*

Storage buildings adapted to a farm are cooled (1) by ventilation with outside air, (2) artificially by ice, (3) by a mixture of ice and salt, (4) by chemical methods of refrigeration. There is wide variation in practice in the construction and arrangement of the various types of storage houses, depending on local conditions and the preference of the builder. This article will discuss the general features of these types of storage houses, giving an idea of the advantages of each, of their construction and of the management. The discussion deals with storage houses for fruit, as fruit is the product usually cold-stored on farms, but the remarks apply with equal force to other products.

A person with a storage house on the farm can hold the fruit crops or other products for satisfactory prices. He is independent of the temporary condition of the trade. The strawberry or the peach may be stored a few days till a temporary glut is cleared up, the pear a month, and later apples several months. The labor can be concentrated on the picking of a crop like the apple; the fruit can be stored at once, instead of ripening and decaying in the orchard while waiting for shipment. The best labor can have permanent employment in the winter if the crop is stored on the farm. The storage house can be used to cool perishable fruits before shipment, and thereby assure a wider distribution and a safer arrival in market.

The common storage house.

Common storage houses cooled by ventilation with outside air are adapted to the storage of the slow-ripening varieties of apples and pears in the northern states, and in high altitudes in other sections where the night temperature frequently falls to 40° or 50° Fahr. during the harvesting season. Under these conditions it is a satisfactory house for a small apple-growing farm. The common storage house is out of place in regions where the fall temperature is generally warm. The construction is cheaper than any other type of house, the management easier and the cost of maintenance is low.

The temperature and the humidity of the common storage house are not under full control, which makes it undesirable in a highly organized fruit-growing business in which it is often necessary to hold fruit late in the spring. The fall is the critical period in the keeping of apples. They must be cooled quickly after picking to insure good keeping. If the climate can be depended on to do this, the common storage building is the most satisfactory type of farm storage house.

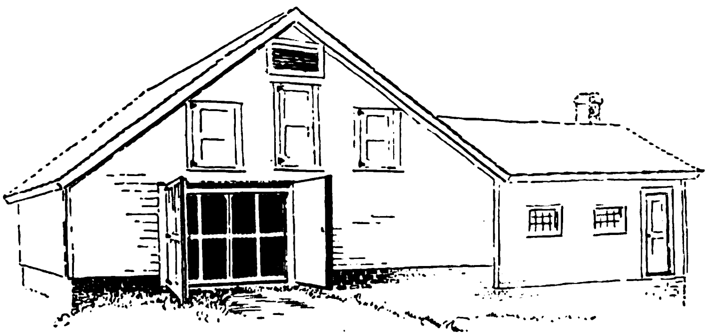


Fig. 348. A type of farm storage house, with grated doors.

The ice-cooled storage building.

An ice-cooled storage building is adapted to sections where ice can be harvested or purchased cheaply. The building is easily constructed, and, if managed carefully, gives satisfactory results when the fall weather is cool. An ice-cooled plant may produce a temperature as low as 34° to 36° Fahr., but in practice the temperature does not often fall lower than 40°. The practical drawbacks in ice-cooled buildings are the slow cooling of the fruit during hot weather, which allows the ripening and the diseases to develop; the poor circulation of air in the room as the fruit cools; the unequal distribution of temperature; the excessive humidity, and the wet condition of the floor and walls in the average plant of this kind. Ice-cooled storage buildings are generally short-lived. The ice tanks leak in time, and the water gets into the insulation and woodwork, causing them to rot. This is the practical history of a large proportion of ice-cooled storage houses throughout the country. These difficulties may be overcome to a large extent by more expensive construction and greater care in management. Figs. 349, 350, 351, from Circular 44, Illinois Experiment Station, show details of ice store-houses.

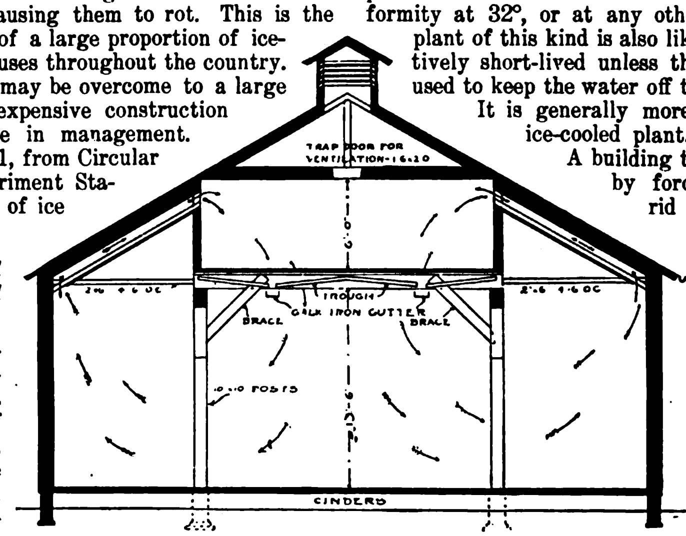


Fig. 349. Section through ice tank and storage room.

A building cooled with ice and salt.

In order to produce a lower temperature and a quicker cooling of storage products, a mixture of ice and salt, instead of ice, is frequently used in farm storage buildings. A temperature of 32° Fahr. is readily attained by using about 5 to 7 per cent by weight of salt, and temperatures as low as 10° to 15° Fahr. can be produced by increasing the proportion of salt. Buildings of this kind are common in New York along the Hudson river, many of them having formerly been ice-cooled buildings but which are now remodeled.

The ice and salt are placed in galvanized iron tubes 10 to 12 inches in diameter, extending from the top of the storage room either along the walls or through the center of the room, or in both positions, to a trough near the floor in which the water is carried off. The tubes extend through the ceiling of the room and terminate in a trough in a room above. They are filled with crushed ice and salt, using about 7 per cent of salt when the fruit is warm, and half as much after it is cool. When the temperature falls below 32° in the mixture, the moisture of the storage room freezes on the pipes, making the air of such a room drier than an ice-cooled room. The "snow" formed in this way has to be chopped off the pipes occasionally. The temperature is varied by the proportion of salt and by the number and size of the pipes in use. If fruit is piled near the pipes it is likely to be frozen. The fruit in the center of the room may be 10° warmer. After the fruit is cooled and the fruit-grower learns to manage the pipes, the temperature can be held with a fair degree of uniformity at 32°, or at any other temperature. A plant of this kind is also likely to be comparatively short-lived unless the greatest care is used to keep the water off the floors and walls. It is generally more efficient than an ice-cooled plant.

A building that is refrigerated by forcing calcium chlorid brine, cooled by ice and salt, through pipes in the storage rooms, or by circulating air that has passed over the cold pipes, is one of the most satisfactory farm storage plants. This is known as the "Cooper Gravity-Brine System." It is similar to an ammonia-cooled storage building, except that the brine is cooled by ice and salt and is circulated automatically. It is the reverse of a hot-water plant in a dwelling-house. An insulated tank is constructed in a room at a level higher than the storage room, and a coil of pipe is placed in this tank and another in the storage room. The two coils are connected and are filled with a solution of calcium chlorid. The tank is filled with ice and salt. The brine in the tank coil is cooled more than the brine in the storage room coil. It

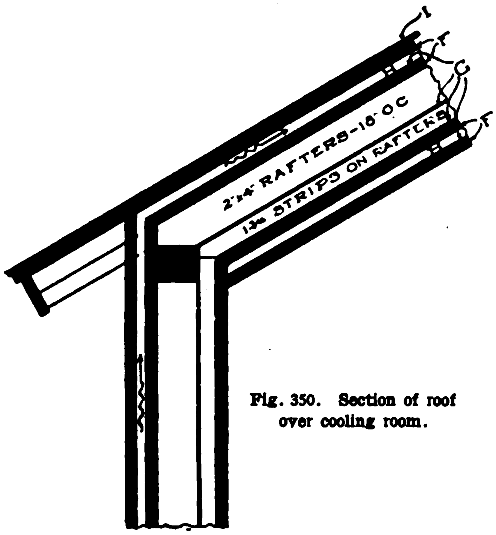


Fig. 350. Section of roof over cooling room.

flows downward because of the heavier specific gravity, forcing the warm brine back to the tank coil. This automatic circulation continues as long as the temperature in the storage room is warmer than the mixture of ice and salt. The temperature in this system is under control. It can be varied by changing the proportions of ice and salt, the size of the tank and the number of coils in the storage room. If the brine in the pipes is below 32° the moisture of the storage room is frozen on the pipes, making a comparatively dry air. The humidity can be controlled further by exposing calcium chlorid over the pipes. The temperature can be maintained uniformly in all parts of the storage rooms after the grower learns to manage the plant. It has all the advantages of chemical storage so far as low temperature and dry air are concerned, and none of the disadvantages arising from the handling of complicated machinery. The first cost of a building is greater than an ice-cooled or an ice-and-salt plant. It is managed more easily than either and at no greater cost, while the efficiency is much greater. This is probably the best type of farm storage building when ice can be secured. A building of this type is shown in Figs. 352, 353, 354.

A building cooled by means of chemicals.

Farm storage plants are sometimes cooled by ammonia or by some other gas on the same principle as the refrigeration of large commercial cold storage warehouses. This system is expensive to install. It requires expert management. It may be used to best advantage in the warmer apple-growing sections. This system, however, is out of the reach of the average fruit-grower unless it can have the same efficient care that a commercial warehouse receives. There are several of these plants in use on fruit-farms. Some of them are unsatisfactory because the installation has been too cheaply done and the management is not sufficiently expert. Under good management, however, a chemically-cooled plant may give ideal storage conditions on the farm.

Requirements in a farm storage building.

Farm storage buildings vary widely in size and cost, construction, arrangement and in other details. They may be built separately or as a part of a building already constructed. All types, except the common storage and the chemically-cooled storage buildings, need to be connected with an ice-storage space which may be a part of the storage building or detached from it. Because of leakage, the ice for the entire season should not be stored above the fruit rooms. All farm storage houses should be provided with a packing room, a storage room for packages and an ante-room or cooling room opening into the storage rooms to prevent the direct access of warm air to the cold rooms. If the building has a capacity of 500 barrels, it should be divided into two rooms to avoid moving warm fruit into the same room throughout the harvesting season. In addition, all farm storage buildings should have thorough systems of ventilation, so as to utilize natural refrigeration by opening the doors and ventilators during the fall to let the fresh air flow into the rooms when the temperature is cold enough. Plans of a gravity-brine cold-storage house are shown in Figs. 353 and 354. The floor plan of this house is adapted to an ice-cooled or an ice-and-salt plant.

The size and cost.—A space of 8 cubic feet is usually allowed for a barrel of apples, including the spacing for ventilation. By storing fruit in square packages, the capacity of a room is increased 10

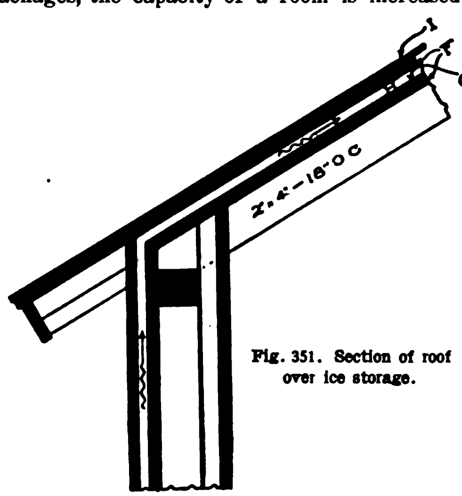


Fig. 351. Section of roof over ice storage.

to 15 per cent over barrels, and by storing in bulk the capacity is increased still more. Some space has to be allowed for corridors between the packages in large rooms. A room 40 x 30 x 7 feet will store approximately 1,000 barrels; one 40 x 40 x 10 feet will store 2,000 barrels, the extra spacing being used by corridors between the packages. A room should not be over 10 to 12 feet in height. A building with 100 barrels capacity can be maintained with a fair degree of success, but the cost of small buildings is proportionally high. A farm storage building should seldom have less than 500 barrels capacity.

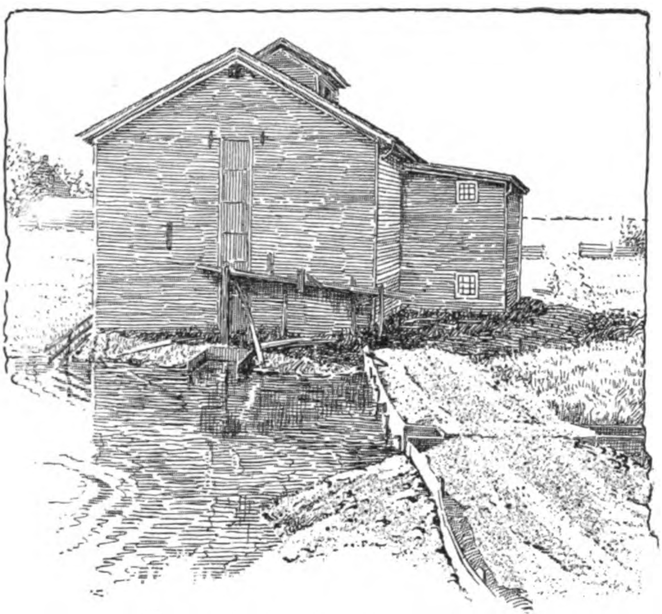


Fig. 352. Gravity-brine cold-storage house.

The cost of the building can be approximated only in a general way, as it is influenced by the construction and by local conditions. A common storage house of 1,000 barrels capacity, one story high, frame, with packing room and storage space for packages, can be built at a cost ranging from $800 to $1,500; a well-built ice- or ice-and-salt-cooled storage plant of the same capacity, including the ice-house, for $1,500 to $2,000; a gravity-brine plant for $2,000 to $3,000; and a chemically cooled plant for $5,000. Larger buildings are proportionally cheaper to construct. An ice-cooled plant of 2,000 barrels capacity can be built for $3,000 to $3,500; a gravity-brine plant for $3,500 to $4,500; while a chemically-cooled plant of 5,000 barrels will cost $7,500 to $12,000.

Construction.—The fundamental requirement in the construction of farm storage buildings is efficient insulation in every part. A uniform temperature is impossible with cheap construction and poor insulation. It is not economy to restrict the first cost of the building too rigidly. The construction is subject to a wide variation in materials and in their arrangement. The material may be brick, concrete, stone or wood. The use of dead-air spaces is the most effective method of insulation. In order to break up the air currents in the space, one of the spaces should be filled with some fine material, such as mineral wool, fine shavings, sawdust, or fine dry cinders. The insulation should always be dry, as a wet filling is worse than none. A dead space should be built on each side of a filled space, or non-conducting materials like P. & B. papers or hair felt used in connection with the board walls. Common storage buildings do not require such perfect insulation.

Location of the ice-chamber.— In an ice-cooled house, the ice-chamber should be located above the storage rooms. It should be built of galvanized iron, and provision made to carry off the water. It may be an insulated box with ventilation on the top, or open if the roof of the building is heavily insulated. It may extend the entire length of the building, but does not need to be more than one-half the width. The cold air may flow through openings in the ceiling at the side of the ice-tank to the rooms below, and the warm air return up the side of the walls of the storage room; or the current is sometimes reversed, the cold air being led down along the walls behind guides and returning through the center of the room. An effective method of distributing the cold air uniformly is made by building a slat oak floor to the ice-box, which rests on 14-inch joists, one foot apart, supported by a girder and posts. The joists are protected from the water by galvanized iron caps, which drain into galvanized iron troughs hanging between the posts. The troughs lead to galvanized iron gutters, from which the water is drained out of the building. The cold air drops directly through the fruit, is deflected toward the walls and rises back of a false ceiling to the top of the ice-box, which has solid sides. This arrangement is shown in Fig. 349.

Refrigeration. — The amount of refrigeration required for running a plant can be approximated only in a general way. It depends on the outside temperature, the construction of the building and other factors. A well-built farm storage house of 1,000 barrels capacity in New York will require the storage of 100 to 175 tons of ice in an ordinary season. Twenty-five to 30 tons of ice will be required to lower the temperature of the fruit to the desired degree of cold, the remainder of the ice being used in the refrigeration of the building and in shrinkage during storage. A house of 2,000 barrels capacity will use 60 to 75 tons in cooling the fruit, and 40 to 75 tons for additional refrigeration and shrinkage. These figures assume first-class insulation and an effective design. A larger quantity will be required for poorly constructed or badly arranged buildings.

If ice alone is used for cooling, the ice box above the fruit storage room should have a capacity of not less than 1 to 1½ cubic feet for every barrel of apples, or for every 8 cubic feet of space in the storage room. The ice tank will need to be iced about once a month during the fall. It is still more difficult to estimate the piping needed in ice-and-salt-cooling. A temperature of 32° can be maintained by using six inches of 10-inch pipe for every barrel, or for 8 cubic feet of space in the storage room; i. e., a room 15 x 15 x 10 feet, which would hold about 280 barrels, would require 16 pipes 9 feet long. In cooling the fruit, 5 to 7 per cent of salt is mixed with the ice, smaller quantities being used after the fruit is cold. A gravity-brine plant of 1,000 barrels capacity will require the storage of about 100 to 175 tons of ice. The proportions of salt and ice are similar to those used in the tube system, though in either the proportions will need to be determined by a few days of experimental work when the plant is started.

Ventilation.—An adequate ventilating system is essential to all kinds of farm storage buildings. The methods are subject to wide variation. In common storage houses, the intake of cold air is at the bottom of a room, and the outlet at the top of the building. The cold air at the bottom may be distributed by flues under the floor and let in through registers. The top needs a ventilator for every 12 to 16 feet of length. The ventilator at the roof may be 12 inches square, and should extend 6 to 10 feet above the roof. The ventilators are opened at night and are closed during the day. When the nights are frosty the doors and windows may be opened. Farm storage houses should be provided with grated iron doors for use at night, and the windows of the common storage houses also. Cold-storage houses, that is, those cooled by other means than ventilation with outside air, do not require windows. The circulation of air can be hastened by installing an exhaust fan at the outlet ventilator.

In ice-cooled storage, and in the other types

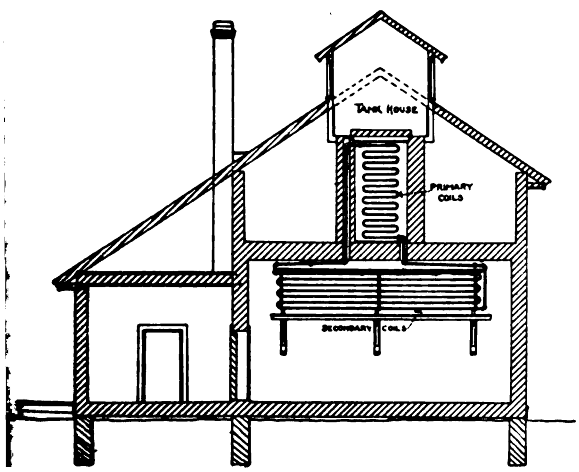


Fig. 353. Vertical section of a gravity-brine cold-storage house.

referred to, the ventilators should be placed in the top of the building. In the gravity-brine system, an adjustable register may be placed in the top of the storage room to let the warm air out of the top of the rooms when necessary.

The ice-house.

A first-class ice-house can be built with 2 x 4-inch studding, lined with P. & B. building-paper inside, then a three-fourths-inch air space made by nailing strips on the studs, then two-ply building-

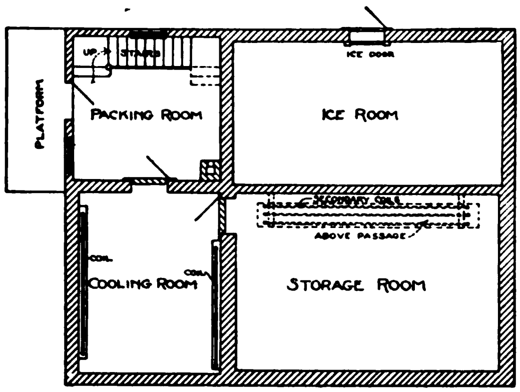


Fig. 354. Horizontal section of a gravity-brine cold-storage house. This floor plan is adapted to an ice- or ice-and-salt-cooled plant.

paper covered with one-inch boards. Outside the studding should be nailed one-inch boards, two-ply paper, a seven-eighths-inch air space allowed, followed by paper, and tongue-and-grooved siding. The air space may be filled with cork-dust, shavings or mineral wool. The roof should have 2 x 4-inch rafters, with one-inch boards, two-ply paper, a seven-eighths-inch air space extending nearly to the peak, and shingles. The seven-eighths-inch air space of the wall should be continuous with the space in the roofing, as shown in Figs. 350 and 351, which show the construction of the walls and roof of a fruit storage and an ice storage house. The gables and the roof should both have ventilators, and the bottom should be tight to prevent the entrance of warm air.

The fruit storage building.

The building should have a good concrete foundation covering the entire floor, or a free air space under the floor, to prevent the insulation of the floor becoming damp. A well-insulated wall may be built like the wall of the ice-house described in the preceding paragraph (Figs. 350 and 351), with the addition of one more dead-air space, one thickness of building-paper and one thickness of sheathing to the inside of the wall. Another wall may be built with 2 x 12-inch studding filled with shavings and protected with boards, building-paper, and siding outside, and boards, building-paper, hair felt, P. & B. building-paper, hair felt, building-paper and boards, in order, inside. The same general construction is used in the floor and ceiling or in the roof in ice- or ice-and-salt-cooled buildings.

A common storage building should have two good air spaces protected with boards and building-paper, but the filled space in the center is not essential. The floor and ceiling should be of the same type.

The handling of a farm storage plant.

The successful handling of a farm storage building is a matter of the careful adjustment of many factors on the part of the owner. The keeping of the fruit depends on the conditions in which it is grown, the handling it receives before it is stored and the conditions in the storage plant. The influence of cultural conditions on the keeping of the fruit is not well understood. It is probable that any condition that causes the fruit to grow with unusual rapidity, such as excessive culture or richness in the soil, a light crop, young rank-growing trees, or quick-acting light soils, is likely to reduce the length of the storage life of the fruit.

Of greater practical importance is the handling of the fruit after it is picked and before it is stored. The common soft rots in apples gain entrance through an abrasion in the skin and grow vigorously if the temperature is not reduced quickly. Other troubles, as the bitter-rot and pink-mold, grow rapidly after picking if the temperature is not reduced quickly to 40° Fahr. Sound fruit and quick storage are fundamentals in successful fruit storage. The owner of the farm storage plant should aim to place the fruit in the storage room within twenty-four hours after picking, leaving the fruit in the cooler air the night following picking.

A variety of packages may be used for storing the fruit. All of these need a circulation of air around them for rapid cooling. Quick-ripening fruits should be stored in small packages in order that the contents may be cooled quickly. In an ice-cooled house where the air is moist, apples may be stored in bins, though the fruit is likely to shrivel if stored in bulk or in open packages in temperatures as low as 32°. A wrapper improves the keeping of all fruits that are to be held for any length of time. It preserves the flavor, prevents the spread of disease and protects the fruit from mechanical injury.

The storage rooms should be kept as near 32° as possible for all fruit products. A temperature somewhat higher keeps the fruit fairly well, especially if it is stored quickly after picking; but if the storage is delayed in hot weather, or if the fruit is intended for a long keeping period, the lower temperature is needed for the most satisfactory results. Frequent ventilation with cold air is essential to the preservation of the quality of the fruit.

Literature.

The literature of cold-storage is scattered, yet the subject is of great importance to modern agriculture, in the storage of fruits, eggs and meats. Because of this scattered literature, a rather full bibliography is here given:

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FENCES AND DEFENCES

One does not think of farms without thinking also of fences. Until recent time there have been no fenceless farms in America. Fences are associated with land and sell with it; and they afford a suggestive commentary on the history and institutions of a country. Originally designed for protection or defence,—the word "fence" is only a shortened form of "defence"—the fence came to be a traditional part of the structure of a place, wholly aside from any use that it may serve. In other words, the fence is not always dictated by reason, but rather by custom. The reasons for fences fall in four categories: (1) for direct use; (2) to mark a boundary; (3) to afford seclusion; (4) to add to the looks or appearance of a place.

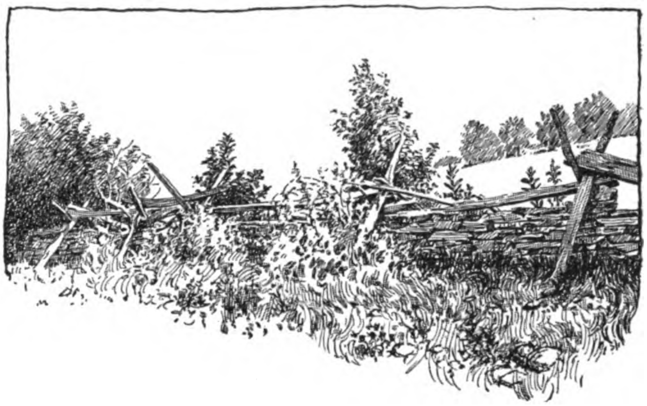

Fig. 355. An old-time fence. A combination of stones and rails. It is continually getting out of order, invites weeds and occupies much land.

Of late years there has been a distinct effort at relegation of useless fences, and persons have wondered why the owners clung to them so tenaciously. No doubt a good part of this tenacity is merely the deep-rooted custom and traditional practice that develop finally into a kind of race instinct, which is all the more difficult to eradicate because no one is consciously aware of its existence. We still wear buttons on the sleeves of our coats. Considering the history of the fence idea, it is surprising how much has been accomplished within recent years in the removal of fences.

The fence may be considered from the point of view of the city man and of the countryman. With the city man it is primarily a question of looks; with the countryman it is a question of utility. In both instances the attitude toward the fence is changing, indicating that old customs and semi-unconscious practices are being challenged and outlived.

The town fence.

Many of the traditional practices have persisted in both country and city, and the fence-building custom is one of them. It was not so very long ago that cattle were allowed to roam in the village as they were in the country, and fences come with cattle. When cattle were removed from the streets, the fence did not go. Persons had come to feel that a fence is as much a part of any place as a walk or a wall is. It had come to be associated with the idea of home. The removal of stock was not sufficient reason for the removal of the fence. At best, such reason was only negative. The positive reason came in the development of what is really the art-idea in the outward character of the home,—with the grading and parking of streets, and the feeling that the breadth of setting for the house can be increased by extending the lawn to the actual roadway. We have now learned that a fence is no necessary part of the plan of a place, that it really does not add to the completeness of the establishment, and, moreover, that it may even introduce a discord with the architecture. The development of the modern American city residence street requires the complete removal of front fences, or at least the reduction of them to a coping.

Fig. 356. Stump fence. Characteristic of certain pine regions.

All this does not mean that fences are everywhere out of place about a home, even if they do not serve as a means of defence against chickens and children and cattle. The large individual isolated establishment may need fences as a part of its structural design, or it may not, depending wholly on what the place is. But the mere street fence of the old time is gone, and the presumption is against the fence rather than for it. Very likely we have often gone too far in the obliterating of fences, throwing our home grounds open to unseemly publicity; but this is a subject which concerns itself with our point of view toward the type of living and toward the rights of the public, more than with fences themselves. If an inclosure is wanted for personal or architectural reasons, it is usually a wall rather than a fence that is needed.

The farm fence.

In the open country a different class of problems arises. Here the fence is distinctly useful; and yet, how many of the fences on most old farms are really needed? The extent of fencing in any country is governed to a large extent by the amount of native material available for fence construction; and yet the eastern farms were fenced beyond all relationship to mere cheapness of materials. The fencing on many an old New York or New England farm was worth as much in original cost and effort as the buildings. Now these fences are being removed. This marks the passing of an old style of agriculture. The small "mowings" and "plowings" and permanent fields are giving way to larger pasture ranges, or to soiling systems, or to rotations, or to other features of a rapidly changing industry. The relative absence of fences in the Middle West is due not only to a scarcity of stone and timber, but also to a different theory of farming.

On farms, fencing is governed by its usefulness. The roadside fence is passing, because it is not needed and because it entails expense, rather than because it is unattractive. The fence is being gradually eliminated in all kinds of farming that does not produce live-stock. The relative amount of capital that can be put in fences is now a subject of careful consideration in all advanced teaching of farm management; and the general tendency is to reduce it, not only from the point of view of cost of fence, but of the area of land that is occupied. In many parts of the country there is a growing tendency toward untidy fence-areas, due to the scarcity of labor; and the reduction of the fences has a bearing on the cleanliness of the farm. In this regard, the wire fence marks a distinct advance.

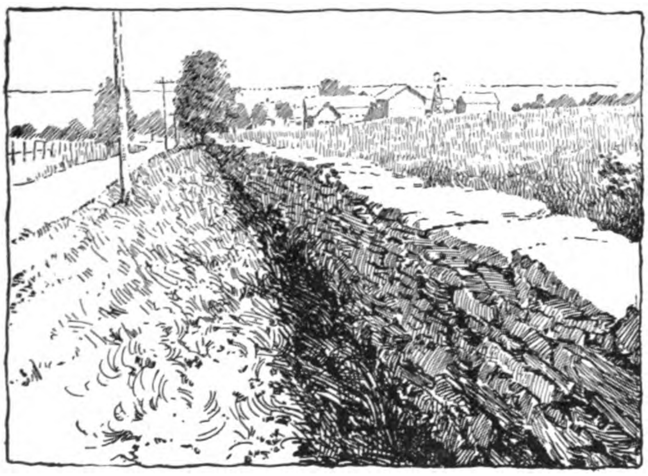

Fig. 357. An example of well-laid stone wall.

The quantity and style of fence have very close relation with the organization of the farm, since the fence follows the rotation or the crop or the utilization of a given piece of land. With the development of more elasticity in farm practice, fences have come to be temporary or movable in many cases. They are no longer so rigidly characteristic of "fields" as they were; and the more business-like management expresses itself in the straighter and directer fences, with less waste land accompanying them. A wide fence-row is indicative of cheap land. While the general tendency has been to reduce the extent of fencing, nevertheless fences are just as important to good agriculture as they ever have been; but they should be directed in every instance by reason rather than erected as a concession to usage.

The observant traveler can find few more interesting subjects of observation than the kind and the relative abundance of fences in the various parts of the country. It is astonishing how many kinds of fences it is possible to construct. The stone wall (which often literally dilapidates into a stone pile), the stump fence, the rail fence, the wire fence,—these all suggest the general character of the region and something of the type of its farming industries. The picket-inclosed garden is often a token of the old idea of a garden as a precious bit of "beds" and plots where accessory and incidental things are grown. Nowadays we have come to think of a garden as a straight-away and resourceful and regular part of a complete farm enterprise. The different kinds of fences also indicate the stage of mechanical ingenuity and skill of a community.

Persons desiring to read on fences should consult, aside from chapters in farm books, the following: The Home and Farm Manual, N. D. Thompson & Co.; Farm Buildings, Sanders Publishing Co., Chicago; Fences, Gates and Bridges, Orange Judd Co., N. Y.; Yearbook 1901, 1904, United States Department of Agriculture, and Farmers' Bulletins, Nos. 235 and 239.

FARM FENCES

By *W. M. Cook*

The farm fence has shown a constant evolution. At first constructed of the crude and heavy materials of the neighborhood,—logs, stumps, stones, brush, rails,—it has now come to be made of well-selected manufactured materials, not only because the native material is becoming scarce but also because of the necessity of economizing both labor and land. The old fence occupied great strips of land, as witness the stone wall and the worm fence; and the resulting fence-row widened the area. In some countries the lessening supply of material has emphasized the value of the hedge, but this fence has never become popular in this country, not even for ornament. Other questions aside, we can not afford the labor required to keep a hedge in good condition, nor the space that it occupies, nor the moisture and plant-food that it appropriates. One by one the various kinds of fencing are passing away, except only the wire fence, of many patterns, and this is becoming characteristic of the farming country.

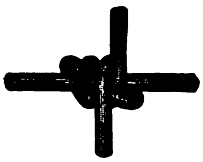

Fig. 358. A good mode of securing a cross-wire.

The fence is not only important for the inclosing of fields, but it gives character to a farm. It may or may not be a thing of beauty. It is one of the first objects to impress a visitor, and it often causes him to form an estimate, possibly unconsciously, of the nature and value of the farm. This impression may not arise so much from the particular kind of fence as from the way in which it is put up, the care it has received, and the many little features that cause it to look important and tidy or unimportant.

The arrangement of fences.

The arrangement of fences must follow the arrangement of fields. Therefore, the fence question involves the fundamental plan of the farm. The shape of the field also modifies the length of fence. Irregular fields may not only require much fence, but the fencing may be difficult to manage, and the fields usually have a cramped or unattractive appearance. The small field is fast giving way to the demands of modern farm machinery. The long, narrow field is better adapted to the larger machines; and this, with the necessity in many cases for longer and narrower fields in order that all may be brought near the buildings, is fast determining the general proportions of the subdivisions. The passing of the many small, irregular-fenced fields is greatly simplifying the fence problem.

The arrangement of the fences has received little attention, and no system has been evolved, as evidenced by the utter lack of similarity in fencing on farms in a community growing the same crops in the same rotation, and having like requirements. Beyond question there is a plan for farm-fencing more economically suited to the farm than the present usage. It is apparent that, when the fields are to be fenced, the fencing for a three-year rotation will not be adapted to a five-year rotation and allow regularity of crops each year. Crop rotation is a potent factor in altering the old fence-row. The scheme of fencing the stock rather than the fields, which is gaining in favor and is most commendable, is further influencing the system of farm-fencing. Farming land is more productive and more easily tilled when not pastured.

Allowing for half of the line-fences and one side fronting the public road, it requires 400 rods of fence to surround a quarter-section, or 160 acres. The same tract divided into 40-acre fields requires 720 rods of fence, or into 10-acre fields 1,360 rods. Estimating the cost of fence at one dollar per rod, the expense of fencing small fields is astonishing. The estimated life of a farm fence is only fifteen years, with an annual repair of 10 per cent on the first cost. When it is remembered that money placed in a fence is never replaced directly, and that otherwise it could be placed at perpetual compound interest, the fence problem becomes a serious one.

The kinds of fences.

While in the farming sections one may find fences of many kinds and constructions, some of which well-nigh bar description, three kinds only are in common use: the board fence, the barbed-wire or simple-strand fence, and the woven wire fence. Of these, the board fence is fast disappearing, the high price of timber at all fit for fencing making its use uneconomical. The barbed-wire fence has been used very widely, but is falling into disfavor, and is being supplanted by the woven wire fence. The latter has demonstrated its worth as a fence for ordinary farm fields, and will find an increasing place on the farms.

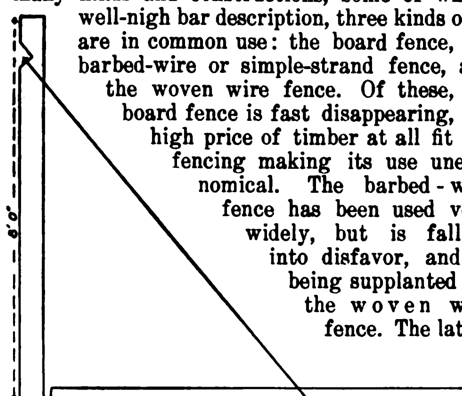

Fig. 359. Tie-back brace for fence post.

A good farm fence must possess the qualities of strength and durability, elasticity and lightness;

and of course it must be high enough, strong enough, and closely enough woven to fulfil the objects required of it. No one of these factors can be overlooked without lessening the utility of the fence. Cheapness in fencing material may not always recommend it. The farmer has demanded a cheap wire and the market has produced it; after a few years the poor grade of wire is useless from the rust. On the other hand, the old wrought-iron wire that was used in fences a quarter-century ago is well preserved and cannot be broken without much twisting. The durability of a wire fence depends not only on the galvanized coating, but on the character of the metal itself. Progressive farmers who take pride in the appearance of their farms will continue to be dissatisfied with fencing which turns red with rust in a year or two, even if it remains stock-tight for a very much longer period. To manufacture a durable wire with an efficient protective coating presents a problem which is being carefully studied and discussed by metallurgists and progressive manufacturers.

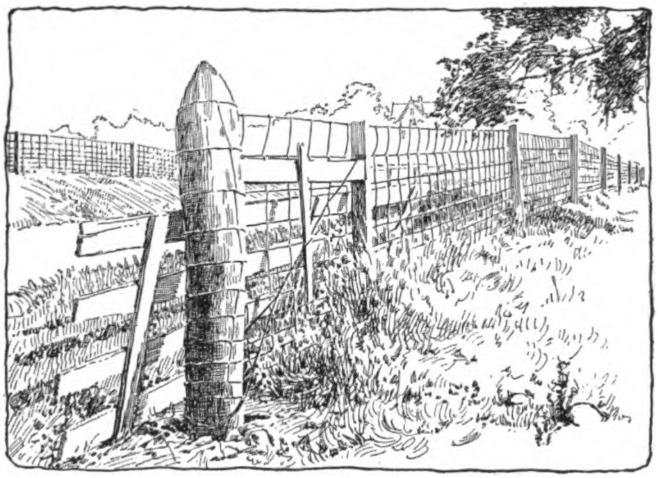

Fig. 360. A durable wire fence, specially adapted to confining small stock.

There is good reason to believe that the future will show a great improvement in the lasting quality of this sort of fencing.

If the fence is to be lasting and serviceable, provision must be made for the contraction and expansion of the wire with changes of temperature. The most satisfactory method has been that of coiling each horizontal wire, under high tension, into a long spiral spring. The high carbon spring wire responds to this method to perfection, as demonstrated in fences now in use for many years. The satisfaction given by such fences has created a demand for the same method at a lower price. A cheaper grade of soft wire has been given the same treatment and woven into fences that are in common use. Such wire soon loses its elasticity and becomes loose between the posts. Another common provision for the changes due to temperature is to twist two wires, as in barbed-wire; this is satisfactory for a number of years, yet two wires of the same strength as one larger one must have more exposed surface, and the wire will weaken sooner by rusting. Ratchets for tightening the wires from one or both ends were once generally

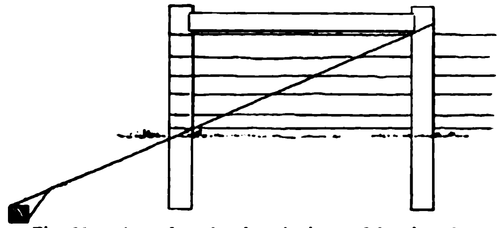

Fig. 361. A good mode of anchoring and bracing the end post.

used, but of late years comparatively few have been sold. They must be loosened to allow for contraction; this is seldom attended to, even by the most careful farmers.

The web of the fence is also of importance. Some otherwise practical fences have too light stay wires. The weakest part will represent the real strength of the fence. For a general farm fence, cross-wires should not be less than No. 12 wire, and of the same quality as the horizontal wires. Many ways of attaching cross-wires in the fence are used, most of which allow the bars to slip from their places. A cross-wire welded or fastened without "give" will in time break with the constant vibration of the fence. A good fastening is shown in Fig. 358. Only fence from the factory can be made tight enough to keep the bar from slipping. The soft wire must be used if the weaving is done by hand, and this is not always satisfactory.

Securing the ends.

After the fence has been selected, its usefulness will depend to a great extent on the way it is erected. If the posts are not well placed the work is wasted. The most important thing is anchoring the end and corner posts, which maintain the tension of the fence. A day or so of additional work on a string of fence is a small matter when compared with the loss and inconvenience of a swagging fence. When farm help is scarce and one has neither tools nor

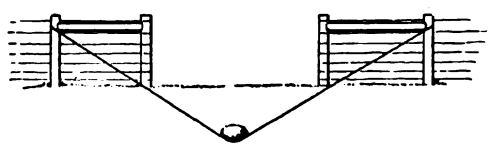

Fig. 362. Mode of bracing a gate.

experience in the work, the most satisfactory way is to have a fence-builder do the work by contract.

Modes of securing the end posts are many. In Fig. 359 is shown a back brace for the end post that is neither very difficult to make nor very expensive. If the post and ground sill or "dead men" are both of locust or some equally good wood, and well placed, they will last a long time. This has the disadvantage of extending beyond the fence into the next field, and may there be a nuisance. A more common method is shown in Fig. 360. The brace post is set in line with the fence, and nine or ten feet from the end post. It should be about the same size as the end post, and set just as rigidly. A wooden brace extends horizontally from about twelve inches below the top of the end post to a notch about ten inches below the top of the brace post. The top of the brace post should then be tied to the bottom of the end post, a strong wire being generally used for this purpose. This is not so good as anchoring and bracing together.

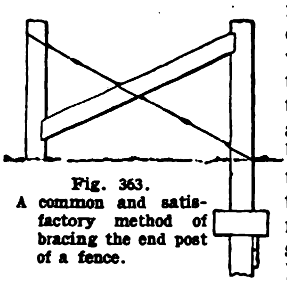

Fig. 363. A common and satisfactory method of bracing the end post of a fence.

A more satisfactory brace is shown in Fig. 361. About 6 feet from the end post is set a line post of good size. It is connected to the end post by a horizontal brace of 6 x 6-inch material, placed a few inches below the top of the posts. From near the top of the line post a cable of twisted wires, of at least six strands, or a three-quarter-inch iron rod, passes down by the foot of the end post, to which it is not attached, to an anchor or "dead man" in the ground. If well placed, this brace will never give way or the posts lose their vertical position. If, on the other hand, the diagonal wire is fastened to the foot of the end post, a slight loss of vertical position is seen almost immediately, and the condition grows worse with time, the post sometimes being raised part way out of the ground. When a gateway comes in the line of a wire fence, a similar brace should be used, merely making it double and the diagonal wire cable endless, passing beneath a stone or wooden "dead man" (Fig. 362). This will insure the rigidity of the gate posts. Another mode of bracing and anchoring is shown in Fig. 363, in which the end post has a collar beneath the ground.

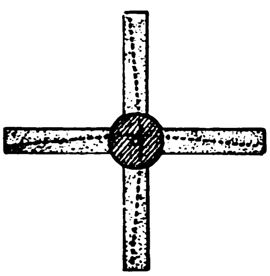

Fig. 364. Cross-section at ground line of cement end post, showing the reinforced cement braces.

A concrete gate or end post is by far the best. It should have a cross-section at the ground line, as shown in Fig. 364. It need not be more than 12 inches in diameter, but must be provided with a good-sized metal bar for reinforcement; a piece of 2-inch pipe will serve. Near the surface of the ground there should be dug narrow transverse trenches forming a +, the intersections at right angles, and in these trenches (which may be 6 feet long) concrete laid at the time it is placed in the post, with metal reinforcement laid in it also, crossing the section of the post. If, then, the excavation for the post be at least 48 inches deep, and the post made right in place, no power will be likely to move it in any direction.

Posts.

The selection of fence posts demands careful attention. The factor which determines their service is probably not so much the kind of wood used, within certain varieties, as it is the climate and soil conditions in which they are placed. Posts will usually last longer either in excessively wet soil or excessively dry soil. Intermittent wetness and dryness is conducive to rotting and other deteriorating influences. While one kind of timber may be especially good and lasting in one part of the country, it may not be so durable in other parts. The following materials make good posts: osage orange, red cedar, white oak, bur oak, red oak, mulberry, white locust, yellow locust, catalpa, chestnut and cypress. Some of these may be discriminated against because of the difficulty of driving a nail or staple into them. Another factor which may reasonably determine the kind of materials to use for fence posts is the expense of securing them. An inferior post may be more serviceable because of immediate supply or lessened expense in procuring it. The life of wooden posts is very limited, and the scarcity of suitable timber in many localities has made it imperative to find a

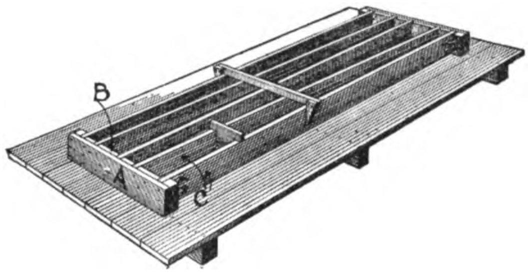

Fig. 365 Mold for making cement fence posts with two tapering sides.


Fig. 366. Wooden mold for making fence posts with four tapering sides. (Farmers' Bulletin No. 235.)

substitute. Iron posts are frequently used for ornamental purposes, but their adoption for general farm use is prohibited by their excessive cost. Then, too, where exposed to the weather, iron posts are subject to corrosion; and if of cast iron they are easily broken by a sudden jar.

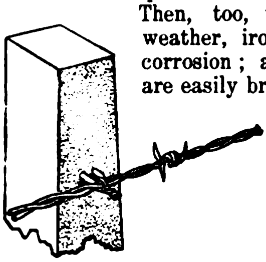

Fig. 367. Detail showing method of attaching wire to concrete post.

Concrete posts.— At the present time, the material which seems most nearly to meet the requirements of a fence post is reinforced concrete. The cost of concrete posts as compared with wooden posts will depend in any locality on the relative value of wood and the various materials which go to make up the concrete post; in most cases, at present, wood will prove the cheaper material in regard to first cost. On the other hand, a concrete post will last almost indefinitely, its strength increasing with age, whereas the wooden post must be replaced at short intervals, probably making it more expensive in the long run. It is not practicable to make concrete posts as strong as wooden posts of the same size; but sufficient strength to withstand the loads they are required to carry may be secured by means of reinforcement, or, in special cases, by using a larger post with a greater proportion of metal, and well braced.

The following advice on cement fence posts is from Farmers' Bulletin No. 235 of the United States Department of Agriculture: "No form of wooden reinforcement, either on the surface or within the post, can be recommended. If on the surface, the wood will soon decay, and if a wooden

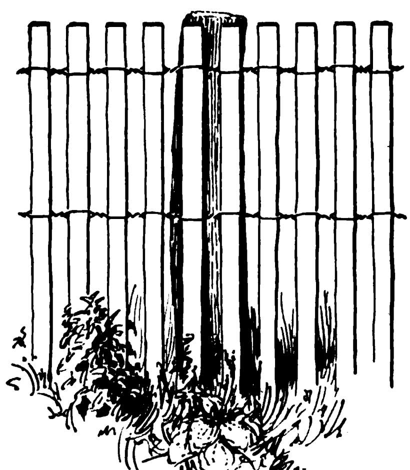

Fig. 368. Method of securing pickets.

core is used it will in all probability swell by the absorption of moisture and crack the post. The use of galvanized wire is sometimes advocated, but if the post is properly constructed and a good concrete is used, this precaution against rust will be unnecessary, since it has been fully demonstrated by repeated tests that concrete protects steel perfectly against rust. If plain, smooth wire or rods are used for reinforcement, they should be bent over at the ends or looped to prevent slipping in the concrete. Twisted fence wire may usually be purchased at a reasonable cost and is very well suited for this purpose. Barbed wire has been proposed and is sometimes used, although the barbs

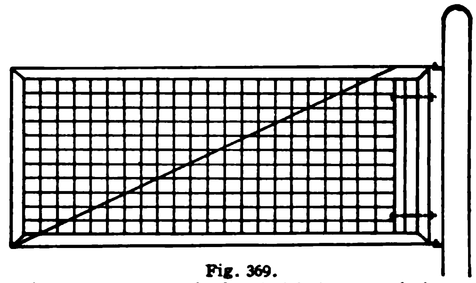

Fig. 369. Serviceable gate made of wire stretched on 2 x 4-inch scantlings. Note the position of the brace wire.

make it extremely difficult to handle. For the sake of economy, the smallest amount of metal consistent with the desired strength must be used, and this requirement makes it necessary to place the reinforcement near the surface, where its strength is utilized to greatest advantage, with only enough concrete on the outside to form a protective covering. A reinforcing member in each corner of the post is probably the most efficient arrangement. The concrete should be mixed with portland cement in about the proportion of 1-2½-5, broken stone or gravel under one-half inch being used. In cases when the aggregate contains pieces smaller than one-fourth inch, less sand may be used, and in some cases it may be omitted altogether. A mixture of medium consistency is recommended on the ground that it fills the molds better, and with less tamping than if mixed quite dry.

"Economy points to the use of a tapering post, which, fortunately, offers no difficulties in the way of molding. All things considered, wooden molds will be found most suitable. They can be made easily and quickly in any desired size and form. Posts may be molded either in a vertical or a horizontal position, the latter being the simpler and better method. If molded vertically a wet mixture is necessary, requiring a longer time to set, with the consequent delay in removing the molds. Fig. 365 shows a simple mold, which has been used with satisfactory results. This mold has a capacity of four posts, but larger molds could easily be made on the same principle. It consists of two end pieces (A), carrying lugs (B), between which are inserted strips (C). The several parts are held together with hooks and eyes, as shown in the figure. To prevent any bulging of the side strips they are braced, as illustrated. Dressed lumber at least 1 inch thick, and preferably 1½ inches, should be used. The post made in this mold measures 6 by 6 inches at the bottom, 6 by 3 inches at the top, and 7 feet in length, having two parallel sides. If it is desired to have the posts square at both ends, the mold must be arranged as in Fig. 366. This latter form of post is not so strong as the former, but requires less concrete in its construction. Great care in tamping is necessary to insure the corners

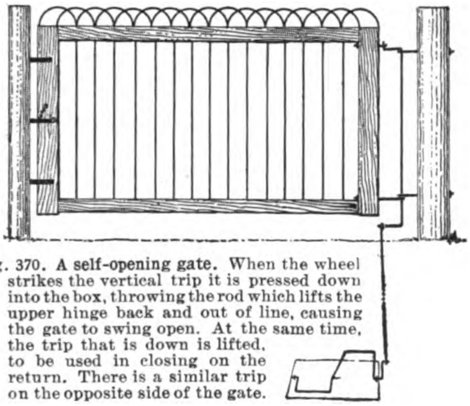

Fig. 370. A self-opening gate. When the wheel strikes the vertical trip it is pressed down into the box, throwing the rod which lifts the upper hinge back and out of line, causing the gate to swing open. At the same time, the trip that is down is lifted, to be used in closing on the return. There is a similar trip on the opposite side of the gate.

of the mold being well filled, and if this detail is not carefully watched the metal, being exposed in places, will be subject to rust."

Stone anchor-walls make good end or corner fence supports, and if made with care will add much to the appearance of the farm. Boulders from the farm are laid in cement, holes being left for the passage of the wires.

The best practice is to fasten the wire on the inside of the posts; that is, on the side toward the field where the stock is pastured. The vertical alignment of the posts must be perfect, or the tension will draw some of the staples. If the corner posts are permanently placed, the others may be replaced without injury to the fence. A mode of securing the wire to the post, from Farmers' Bulletin No. 235, is shown in Fig. 367.

Portable fences.

It is often desirable to have portable fences that may be quickly set up and quickly removed. It is not long since rails were laboriously moved from place to place for temporary inclosures; but of late years portable wire fences have come much into use. A roll of woven wire fence will be found useful on every farm keeping stock. It may be quickly strung across a field, and as easily removed. Many efficient portable wooden fences are also in use. A good fence is made in sections or panels that fit into triangular jacks notched at the top where the side pieces cross, and in the bottom piece.

Gates.

Good fences give little satisfaction unless the gates are closed, and are strong enough to turn the stock. When gates are in constant use it is imperative that they swing freely. A common style that requires hand-lifting is the board gate that slides part way open on wooden crossbars before it swings. The chief advantage of this gate is that it reduces the strain on the posts to a minimum. The more common form is the hinged gate. It is easily swung, but there is difficulty in keeping the posts in position so that the "nose" will not drag. The posts must be most carefully set and be sufficiently large and strong to bear the continued strain of the gate. This demands more than ordinary care, especially when wooden posts are used. Well-made cement or stone posts give the most satisfaction in the long run.

Many styles of gates are in common use, most of which give satisfaction. In fact, the satisfaction depends much less on the style of gate than on the success of the hanging. The gate may be made to swing both ways on simple iron hinges. Or, it may be pivoted in the center and when open will allow two teams to pass through at the same time. This calls for two driveways, one on each side of the center or pivot of the gate. In Fig. 369 is shown a wire gate that may be made of any woven wire fencing. The wire is fastened to one end of the gate, and at the other end to the bar that fits inside of the top and bottom railings; this is attached by two bolts to the upright frame of the gate and drawn to it until the wire is as tight as desired. A convenient and light brace to keep the gate from sagging is made by fastening a No. 9 wire to the outward lower corner and at the upper and hinged end to a ratchet placed in an an angular depression on the top of the frame. This structure is light and will serve the purposes ordinarily required of a gate. The board gate is heavy of itself and on the posts; its own weight will in time warp the braces and allow the point to rest on the ground. When boards are placed side by side, water is held, and rotting will result.

A self-opening gate that has been in constant use for more than twenty years and is still swinging to the same locust posts, is shown in Fig. 370. The gate is framed from oak with upright iron rods bent to a half circle at the top. The hinge will

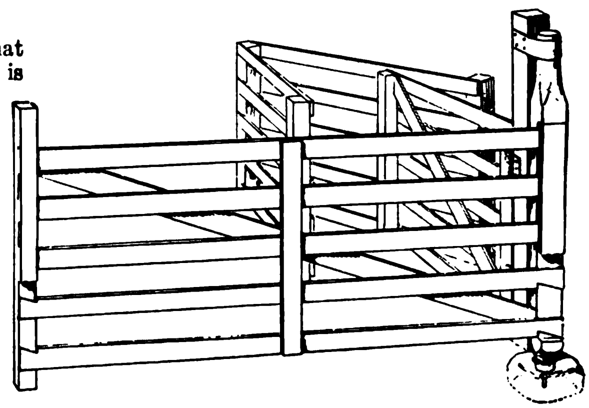

Fig. 371. A pair of good farm gates. The large one in front is for stock and teams. The small gate is for persons; it is always closed, as it swings in a pocket of the fence. These can be used with wire fences, also.

open the gate only one way, but as the top hinge is only a bent rod there is no mechanism to break. As the wheel throws the trip, the top hinge is drawn back and to the side to which the gate has been arranged to open. This pulls the top of the gate back and free from the latch, and, the hinge now being out of line, the gate swings open; likewise it is closed as the wheel passes over the trip at the opposite side of the gate. A third post must be placed to hold the gate open as the spring latch strikes it; as in opening, the hinge at the top is again thrown by the trip out of line and back, thus lifting the gate away from the post so that it is free to swing shut with its own weight. Such a gate is most convenient at the end of a private drive leading to the public road. Gates similar to these are advertised, yet few, if any, are so simple as the one shown.

CHAPTER VIII

SANITATION, AND WATER-SUPPLIES

OF ALL PERSONS, the farmer should be best provided with healthful surroundings. He has room, sunlight, clean air, exercise, normal sleep,—blessings so indigenous that he does not know their value; he does not realize the necessity of giving attention to sanitary surroundings. There are no energetic boards of health to look over his premises. He is so separate that the neighbors do not complain. He has taken health for granted. His exercise is likely to be only work, and it may not develop his physique or contribute to the preservation of health. The number of crooked and bent persons on the farms is very great. The city man is likely to have a better carriage. Probably no persons are in greater need of physical training and setting-up than the farmer, to correct the effects of his daily occupation and to keep the body resistant and resilient.

In food the farmer has distinct advantage, since he buys less than other persons, and by that much is free from the dangers of contamination and adulteration. It is said that the farm cooking is not of the kind to produce the most sanitary results, but it undoubtedly is superior in this respect to the fancy and sophisticated cooking of many of the hotels and clubs. It has the merit of simplicity and veracity. All cooking is being restudied from the standpoint of rational scientific practice, and mere conventional dishes must go. We shall cook with less labor and better results when we learn the reasons underlying the practice. There will be a reaction against many factory-made food supplies, and a consequent reviving of home-made products. Even non-manufactured products, as fruits and vegetables, may be contaminated by exposure in stores and by much handling.

The great emphasis in maintaining health must be placed on sanitation rather than on medicine. Physicians have studied morbid processes more than sanitation; in time, we shall have colleges of health rather than colleges of medicine. In time, also, it will be the first duty of schools to teach persons how to live; now most persons learn only by experience, and life is half gone before the significance and application of the experience are apparent. The science and practice of sanitation are yet new, but we now have sufficient knowledge to guide us to rational lines of procedure. Sanitation rests on two fundamentals: keeping the body in normal condition and function; excluding sources of contamination. The conditions and practices that will keep the body in normal function vary with every person. This means that the person must study himself. Every person is experimenting with himself every day. He should watch the result of this daily experience as carefully as he would watch the growth of crops or the behavior of a favorite horse. When the person has arrived at adulthood he should know himself, and what is good for him and what bad in the common routine of life, better than any other person can possibly know.

It is so easy to say that pure air, abundant sleep, cleanliness, wholesome food and drink, active exercise, moderation in all things, and a calm mind are essential to perfect bodily function and long days that the statement makes no impression on us. Yet it is just these things that will finally release us from Bright's disease and dyspepsia and the larger part of functional disorders and relieve us from "treatment." All these things may be the farmer's if he knows how to avail himself of them. Most of us halt through life and hasten to the grave by sheer neglect of the plainest conditions to health and ignorant or thoughtless abuse of the good body with which we were born. The keynote of it all is to be satisfied with plain and simple things, reserving all the surplus appetite and energy for strong and honest work and for the enjoyment of what comes naturally and in due season.

The Editor has no mind to turn preacher; but there is need of saying that health lies in the use of conditions and opportunities rather than in the patronizing of the drug-store. Some day, residences and schoolhouses and churches will be ventilated as rationally as the best cow-stables are now ventilated. Every good farm dwelling will have running water, and a bathtub that is often used. Water-supplies will eliminate much of the constipation and remove unsanitary conditions. Dust-trap mouldings and casings and hangings will be no part of a human habitation, and houses will be cleaned by taking the dust out of them rather than by moving it from place to place by the use of "dusters." Dish-washing will be reorganized, for many utensils need to be sterilized as well as merely cleaned of the visible materials. Milk and other food will be kept clean and free of contamination. Streams and springs and wells will be looked after. Animals will be kept healthy in order that the humans may also be healthy. Ways will be found of doing all this, and much more, not by adding to the labors of householding but by reorganizing the whole procedure and by making it rational and therefore simpler and directer.

The ways of relieving the stress and burden of household work, to the end that the home may be more sanitary and less wasteful of nervous and muscular energy, are mostly of three kinds: simplifying the living; constructing more rational buildings; introducing better mechanical appliances. The chief labor of the household revolves about the preparing of food and the cleaning of the house. Both of these are not only consuming of labor, but are directly concerned with health, for food provides the sustenance and the house harbors dust. The buildings have been discussed in the foregoing chapter. A paragraph may be given here to the living and another to the appliances.

The amount of energy consumed in the preparation of food and the consequent washing of dishes is beyond all reason. There is no kind of sense in having such an enormous variety of food as most human beings in good circumstances devour. It is merely a concession to custom. It would seem as if our measure of a competency is the number of kinds of food and the quantity of it that we are able to pile on our tables. A first-class hotel has come to be a place that supplies no end of things and of service that nobody should want. A few wholesome and clean articles of food, thoroughly well-prepared and in sufficient quantity, should satisfy the ordinary course of one's life; yet we search the earth to discover new things that can be eaten, most of which satisfy only appetite and not digestion and the demand for which is psychological and not gastronomic. One can be satisfied as well with a plain moderate variety as with the endless articles and mixtures that we now consume; and in time there will be an awakening to simplicity and temperance in eating as there now is to drinking. When we change our attitude toward the dining table, we will reduce the labor of preparing food, and half the work of cleaning dishes—which is now irrationally done, for the most part—will be at once eliminated.

Fig. 372. A pleasant and sanitary setting for a farmhouse.

Having reduced the necessity for much of the household labor, we shall alleviate the burden of the remaining part of it. This relief will come in part through really good and simple mechanical appliances. Our attention to machinery has been given mostly to the invention of large and elaborate mechanisms for field work and manufacture. We now need machines to relieve the daily work about house and barn. In time every complete residence will be provided with light power, which will run simple and effective machines to aid in the laundry, kitchen work, small dairy, pumping of water-supplies, to carry burdens on accustomed routes between rooms and buildings, and to save human strength and administer to comfort in many other ways.

A complete and fundamental reorganization of our household activities, resulting from a change in our point of view on life, will relieve householding of the greater part of its present toil and anxiety; and the result will accrue in better health.

Supervision of health conditions, by means of some kind of boards or inspectors, will come for the country as it has now come for the city, and quite as much for the protection of the city as for the protection of the country. The agricultural colleges are beginning to force these questions in the teaching of subjects relating to home-making, for the country must live up to its full opportunities.

Some of the literature on sanitation and water-supplies, especially with reference to rural communities, which is accessible to farmers, is given below, most of it having been suggested by the authors of the articles that follow: Public Water-Supplies, Turneaure and Russell; Handbook on Sanitation, Price; A Guide to Sanitary House-Inspection, Gerhard; Sanitation of the Country House, Harvey B. Bashore; Water-Supply, Mason; Water and Public Health, Fuertes; The Chemistry of Life and Health, Kimmins; Foods, Smith; The Earth in Relation to the Preservation and Destruction of Contagia, Poore; Bacteria, Newman; Mineral Waters, Report of Missouri Geological Survey, 1892, Schweitzer; Artesian Waters, Iowa Geological Survey, Vol. 6, Norton; The Farmstead, I. P. Roberts; Theory and Practice of Hygiene, J. L. Notter; Principles of Hygiene, D. H. Bergey; Treatise on Hygiene and Public Health, Stevenson and Murphy; Bacteria, Yeasts and Moulds in the Home, H. W. Conn; Trans. International Health Exhibition, London, 1884 (contains papers applicable to rural districts); Proper Disposal of Sewerage Wastes in Rural Districts, Julius Nelson, Bulletin No. 166, New Jersey Agricultural Experiment Station, June 27, 1903; Sanitary Conditions in the Home and on the Farm, Haven Metcalf, Bulletin No. 89, South Carolina Agricultural Experiment Station, 1904; Sewage Disposal on the Farm and Protection of Drinking Water, T. Smith, Farmers' Bulletin No. 43, United States Department Agriculture, 1896; Practical Suggestions for Farm Buildings, George G. Hill, Farmers' Bulletin No. 126, United States Department Agriculture, 1901; Distilled Water for Drinking Purposes, Farmers' Bulletin No. 124, United States Department Agriculture, 1901; How Insects Affect Health in Rural Districts, L. O. Howard, Farmers' Bulletin No. 155, United States Department Agriculture, 1902; Mosquitoes, L. O. Howard, 1902; Milk, Butter and Cheese as Carriers of Infectious Disease, Veranus A. Moore, Yearbook, 1895, United States Department Agriculture, p. 431; Water-Supplies for Farm Residences, H. N. Ogden, Bulletin No. 29, Cornell Reading-Course for Farmers, 1906 (contains the greater part of Professor Ogden's article in the present chapter, the article having been prepared specially for this Cyclopedia); Dust as Related to Food, R. A. Pearson and others, Bulletin No. 18, Cornell Reading-Course for Farmers' Wives; Sanitation of Farm Buildings, J. Scott, Trans. Highland and Agricultural Society, Scotland, 1897, pp. 40–60.

GENERAL VIEW OF FARM SANITATION

By *Severance Burrage*

The fact is too commonly overlooked that sanitation is concerned with many things other than the water-supply and the disposal of sewage, and dry foundations for the buildings. The orientation of the house, the planting about it, the construction, heating and ventilation of the house, the furnishings and general care of the house, and, in fact, all the factors that have to do with the health of the persons and stock in the home and on the farm are more or less closely related to farm sanitation, and must be considered in a discussion of that subject. It is the purpose of this article to treat briefly of the more important of these factors.

Location of the house.

In choosing a site for a farmhouse, the following factors should be considered carefully at the start: the character of the soil and its elevation relative to the surrounding country; the proximity of forests, deserts or bodies of water; the geology of the region; the possibility of proper drainage and disposal of household wastes; a pure and sufficient water-supply; safe distance from barns and other outbuildings.

Porous soils, that is, gravel and sand, are the most healthful. They allow air and water to pass through them. The level of the ground water in such soils is not constant, depending largely on the amount of rainfall. The rise and fall of the ground water creates a respiration or ventilation of the soil which is most valuable. Rock or clay beds do not permit a free passage of air and water, are not easily drained, retain moisture on the surface, and are consequently unhealthful. It is a problem of great difficulty to drain properly a heavy clay soil. Such a soil should not be used for the site of a dwelling unless properly drained. Proper drainage of soil requires that the level of the ground water be six feet or more below the surface, some authorities requiring that it be at least ten feet.

A southern exposure is desirable, and every effort should be made to secure sunlight in each room in the house at some time in the day. The value of sunlight as a promoter of health and preserver of wholesome conditions cannot be overestimated. The living-rooms should be so placed as to receive the maximum amount of sunlight. The windows of such rooms should be protected in the warm weather from the heat and glare of the sun, by blinds, awnings or trees. Trees in moderation about a house are a benefit, but tree-planting is easily overdone, shading the house too much and making the surroundings damp. Trees tend to prevent the free circulation of air (Fig. 373). Barns and other buildings should never be placed so as to prevent the sunlight and air from reaching the dwelling.

Aside from the general conditions of dampness prevailing near swamps and bodies of water, the fact that these places afford a breeding-place for the mosquito renders them undesirable neighbors.

The old idea that malaria is caused by an effluvium having its origin in swamps and damp soil no longer prevails, for it is known that certain kinds of mosquitos are the spreaders of malaria and malarial fevers. Even the rain-water barrel should be covered, to prevent the access of mosquitos to lay their eggs. Temporary pools and puddles of stagnant water should be dispensed with; and permanent ponds should be covered with coal-oil during the breeding season of the mosquito (See page 287).

General construction of the house.

Care should be exercised in the construction of the house in regard to the general safety of its inhabitants. The persons should be protected at all times from the weather, sudden changes in temperature and wind- and rain-storms. The timbers used in construction should be of sufficient strength to bear all loads coming on them, even under exceptional circumstances. The roof should provide the necessary protection, and be able to bear the snow.

It is essential that the foundation and walls be as dry as possible. When the soil is damp, a satisfactory condition can be secured only by draining the subsoil below the foundation; and aside from this the foundation walls and cellar floors should be cemented. A cellar is always advisable, but should there not be one, the ground floor should be raised two feet or more from the ground, thus permitting thorough ventilation beneath the house. The cellar should be carefully constructed in order that it may be dry. A damp cellar is much worse than none. Care should be taken to make the cellar as light as possible, having as many windows on the sunny side as the construction of the house will permit. The windows must be arranged to open and close easily, and should be kept open during the dry weather. This will be of great assistance in keeping the cellar well-ventilated, dry, and free from odors.

The private house, particularly one in the country, rarely has a system of ventilation. A well-built house, however, needs much ventilation, especially when it is artificially heated. The most common method of heating the farmhouse is by wood, coal or gas stoves. Such a method is undesirable because it heats the room or house very unevenly; heats the same air over and over, with no supply of fresh air except that which seeps in through cracks in floors and about windows and doors. It often happens that poisonous gases are given off through the heated metal of the stoves, which result in headaches and other ailments.

If stoves are to be used, the only ones that are advisable from the sanitary standpoint are the so-called "jacketed" stoves. A jacket of wood, lined with galvanized iron or asbestos, is constructed around the stove and connected with the outdoors by a pipe or cold-air box. The fresh air enters the jacket from below, is warmed in passing up around the stove, and enters the room through outlets at the top of the jacket. In this way the room is much more evenly heated, and is supplied with fresh air without creating any noticeable drafts.

The house that has a cellar may be supplied with a hot-air furnace, which is in reality a modification of the jacketed stove mentioned above. By this method, a pipe carrying the heated air goes to each room. The air thus heated is supplied to the furnace through a cold-air box. Whether the cold-air box is to supply the jacketed stove or the furnace, the outer opening should never be placed on the side of the house near such air contaminators as privies, manure heaps, stables, henyards, piggeries or garbage cans.

Fireplaces are excellent room-heaters in moderate weather, and provide a most desirable ventilation, but they cannot be relied on in extreme weather. Systems of steam and hot-water heating are becoming very popular and are the most reliable systems. They heat the house comfortably and evenly, but have the objection from the sanitary standpoint of not providing any means of ventilation. If such a system is installed in the country home, some provision should be made for supplying fresh air, for in a well-constructed house there will not be sufficient supplied through cracks in the floors, walls and about windows and doors. There are many simple devices for placing in windows, some of which can be made at home, that act as excellent ventilators. One of the simplest of these is a narrow board, say three or four inches wide, placed beneath the lower sash so as to raise the upper edge of this sash above the level of the bottom of the upper sash. This forms an opening between the two sashes, by which a current of fresh air enters and passes upward toward the ceiling.

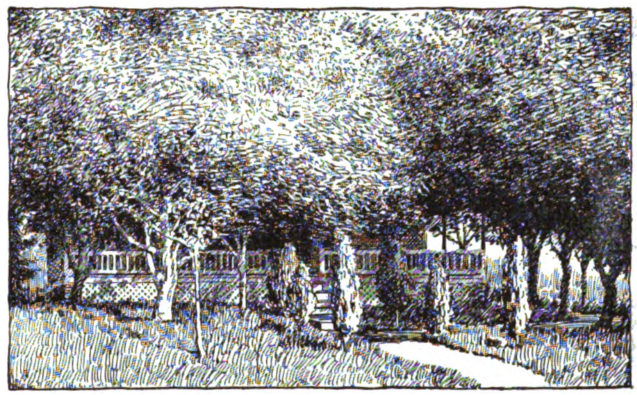

Fig. 373. Overplanting of trees, preventing access of light and circulation of air.

When artificial methods of heating are used, some means for providing moisture for the heated air should be supplied. In the hot-air furnace there is a regular water-pan for this purpose, which should be kept filled. Substitutes for this should always be provided with the jacketed stove, or other method of heating. The moisture thus supplied adds greatly to comfort and healthfulness.

Rigid attention should be paid to the plumbing of the house. Poor plumbing will have a direct effect on the health of the occupants. All the piping should be placed on an inside wall, not on an outside unprotected wall. This will prevent the too common freezing of the water- and drain-pipes. Each sink, wash-basin, bathtub, water-closet, or like fixture, should be connected with the drain-pipes by proper sanitary traps. Drain air and sewer gas must be kept out of the house. While disease germs do not exist in such gases, it is a well-established fact that the poisonous gases from

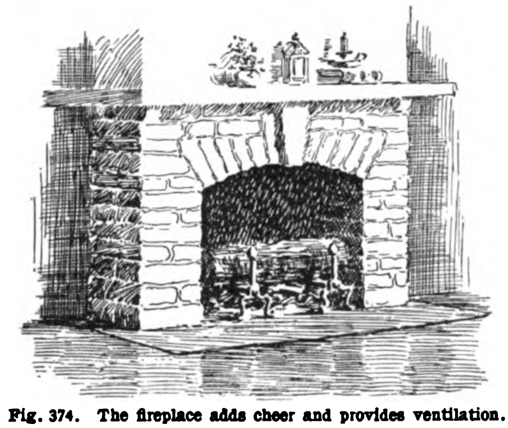

Fig. 374. The fireplace adds cheer and provides ventilation.

drains and sewers, when constantly taken into the lungs, make one susceptible to many of the transmissible diseases, such as typhoid fever, diphtheria and consumption.

Furnishings of the house.

Finished hardwood flooring is the most sanitary. The cracks between the boards should be well filled; otherwise they become collecting places for dust and dirt. Ordinary pine boards, between which the cracks are well filled, and the whole covered with two or more coats of floor paint, make an excellent sanitary floor. There are several so-called crack-fillers on the market that are serviceable and inexpensive. Carpets are usually unsanitary. They are the worst dust-collectors that can be devised. When carpets are laid on a floor in which the cracks have not been carefully filled, the conditions are as unsanitary as possible. With the finished hardwood or painted floors, rugs may be used, and may be removed and cleaned at frequent intervals; carpets are seldom thoroughly cleaned.

All the woodwork and finishing of the interior of the house should be constructed with the idea of its ultimate cleanliness,—that is, the possibility of keeping it clean with the least possible labor. With this in view, the interior woodwork and wooden furniture should have as little fancy work, carving, cracks and crevices, as are consistent with usefulness and beauty.

Some attention should be given to the wall paper or other wall coverings. Papers containing bright green colors, if cheap, may contain arsenic. Poisonous material is continually given off from such arsenic papers, and the inhabitants often show symptoms of chronic arsenic poisoning. While there is not the danger from this that there has been in years past, because of legislative action, still there is occasion to use great care in the selection of wall papers. All heavy hangings, draperies, curtains, and the like, should be avoided. They are great dust-catchers and retain the dust much the same as carpets. They do not permit of frequent cleaning.

Disposal of sewage.

The common form of privy,—a hole in the ground, with the outhouse structure over it,—is one of the greatest banes of sanitary science. It is the source of foul odors; it is the contaminator of the soil in its vicinity; it may pollute the water-supply; and it is the breeding- and feeding-place of flies and other insects that spread the foul and often disease-producing material everywhere.

Of all the wastes from a house, the human excreta are the most dangerous. They contain the germs that cause disease. While excreta from diseased persons are the most dangerous of all, yet all human excreta, even from healthy or apparently healthy individuals, may contain disease germs. Hence, it is readily seen how unsanitary the usual form of privy must be.

The simplest sanitary method of sewage disposal in the country house is by the dry-earth closet. The excreta, including the urine, are received into a galvanized bucket or water-tight box, which can be removed easily. Each person, after using the closet, must throw down a scoop-full of dry earth, dry garden loam, or sifted coal ashes. This will absorb foul odors, prevent putrefaction, and to a great extent remove the possibility of flies or other insects gaining access to the filth. The precautions to be observed in the construction and use of the dry-earth closet are: (1) The galvanized bucket or water-tight box should fit closely up under the seat to catch all the excreta, both liquid and solid. (2) The supply of dry earth or coal ashes should be generous, so that at no time will there be exposed excreta. (3) The bucket or other receptacle should be emptied at frequent intervals. In the summer the material may be used as a fertilizer, turning it in with the garden soil. Its value as a fertilizer may be somewhat increased by the addition of small quantities of sulfate of iron. It is evident that this can not be done unless the quantity of dry earth or ashes has been generous. (4) The earth or ashes must be dry to be effective. Road dust is good. A supply may be put by in summer.

In the more pretentious country residences, in which there is a large water-supply, with the accompanying wash-basins, sinks, bathtubs and water-closets, special provision has to be made for disposing of the sewage. There are several undesirable methods. One is to have the drain-pipe carrying the sewage empty into a brook, creek or open ditch. When this is done, the water of the stream or ditch becomes at once polluted and is a source of unhealthfulness to man and beast. This method is inexpensive, commonly practiced, but unsanitary.

Another undesirable method is to have the drain-pipe lead to a "dry well," a hole in the ground that receives the sewage and allows it to ooze away into the ground. By this method the ground is soon saturated with filth, and thus becomes a source of contamination to air and water in the vicinity. When the filth is thus remote from the cleansing effects (oxidation) of the atmosphere, and also out of reach of the purifying action of plant life, it remains a permanent form of pollution and source of danger.

The water-tight cesspool, if properly trapped from the house, securely covered and ventilated, emptied often enough to prevent overflowing, or in other ways becoming a nuisance, may be an unobjectionable method of disposal. When emptied, however, the problem arises of disposing of the contents. This must be spread on the ground, and, to be effective, should be spread over a considerable area, so that the layer may be thin, thus exposing it to the rapid purifying action of sun, air and plant life.

Better than this cesspool, however, is the "cesspool series," corresponding to the septic tank process, as it is called on the larger scale. In this series, the first cesspool, receiving the sewage directly from the drain-pipe, acts as a settling tank. The outlet from this tank leads to a second, and then an outlet from the second to a third, thus forming a series. These tanks can be tightly covered, and the sewage is so far purified by the action of the putrefactive bacteria that the effluent from the last tank may be used for irrigation purposes on the farm without nuisance or danger to health. Large water-tight barrels or hogsheads may be

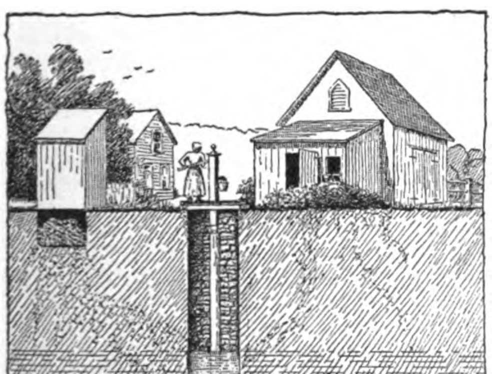

Fig. 375. Unsanitary relations. The shading shows the probable course of seepage.

used for these tanks, sunk in the ground, with pipes leading from one to another. These would be of sufficient capacity to care for the sewage of the average farmhouse. [See article by Professor Ogden, pages 297, 298.]

Careless disposal of wastes from the farmhouse is one of the most prolific sources of disease. Too much emphasis cannot be placed on these features of farm sanitation. The slops from the kitchen (dish water, laundry water, and the like) should be drained away in such a manner as not to create a nuisance of any kind in the vicinity of the house. This is not a difficult problem when the cesspool method of disposal is employed for the other household wastes; but when the dry-earth closet is used, some way must be substituted. Although not a good method, there may be no serious objection to draining the kitchen and laundry wastes into ditches, streams or dry wells, if the streams do not furnish water-supplies to other families. They should not be thrown on the ground just outside the kitchen door, as is the common practice in the country.

Fig. 376. A poorly protected well.

Water-supply.

The subject of water-supply for the farm is treated at length in accompanying articles, and will be only mentioned here. The shallow-dug well, the cheapest and most common form of country water-supply, is universally condemned by sanitarians because of its being invariably liable to both subsurface and surface contamination. In Fig. 375 are shown the conditions when underground contamination is involved. The proximity of the privy to the well produces the subsurface pollution; and the loose board covering of the platform over the well in Fig. 376 affords the opportunity for wastes from the kitchen and filth from farm animals, including poultry, to gain access to the water. Another not uncommon method of surface contamination is shown in the illustration, Fig. 376, of the man taking his morning ablution at the pump. Animals may contaminate well-water, both by surface and underground pollutions. Fig. 377 shows a not uncommon means of contamination. Shallow wells are the greatest source of typhoid fever in the rural districts.

Purification of water.

The problem of water filtration seldom arises for the rural house, as the expense of installing an effective filter, in addition to the other water-supply features, makes it almost prohibitive. It is enough to say that the average filter devised to be attached directly to the water-faucet cannot be depended on for removing disease germs. If the water is suspected of containing disease germs, the safest method of killing them is by boiling. Suspicious water, boiled for ten minutes, will be free from all germs likely to produce disease. None of the water-borne disease germs can resist such treatment.

It is often convenient and desirable to have a supply of distilled water. For this purpose, there are a number of inexpensive water stills on the market. But stills may be made more cheaply by any tinsmith, directions for which may be found in Farmers' Bulletin No. 124, United States Department of Agriculture. These stills are suited for use on the ordinary kitchen stove, and will produce seven to twenty gallons per week, according to the constancy of the fire. Distilled water is very useful in many functional disorders.

General care of the house.

The presence of dust in the air we breathe is a menace to health. It exists in any room where people live or come together. It may affect the human body either simply by its presence acting as an irritant to the delicate membranes lining the air-passages to the lungs, or by actually conveying the disease germs which may form an invisible part of the dust. The removal of dust by sweeping and dusting is one of the principal factors in household cleanliness.

To clean a room or a house thoroughly by sweeping is an art. The usual dry broom method is objectionable for at least two important reasons, one being that it does not remove all the dust and dirt, but stirs much of it up into the air, from which it will settle back into other places in the same or other rooms; and the other, that the person sweeping has to breathe an air saturated with dust, which is both unpleasant and unhealthful. The proper mode of sweeping is to spread on the floor a liberal quantity of wet sawdust, tea leaves, bran, or similar substance. With a dampened broom, there will then be very little if any dust rise into the air. In this way all the dust is removed with the sawdust or other substance, and may be burned or otherwise disposed of. The important point is that it is actually removed, not simply displaced.

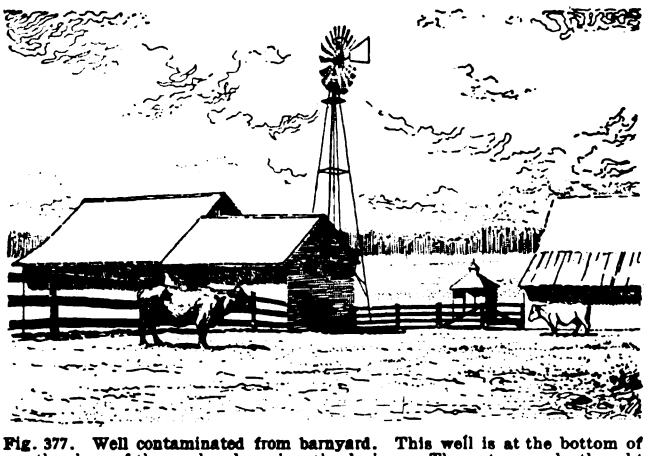

Fig. 377. Well contaminated from barnyard. This well is at the bottom of the slope of the yard and receives the drainage. The water may be thought to be pure after its passage through six to twelve feet of sand, but it is probably unsafe to use.

When there are hardwood floors, a damp mop may serve the purpose without the use of a broom. The whole process depends on the well-established fact that germs and fine particles of dust will not leave damp surfaces.

This same general rule may be applied to dusting. The old-fashioned feather duster is the worst possible implement with which to perform the operation called "dusting." It has not even the quality that the dry broom has of removing some dust and dirt, for it removes none. It is an excellent displacer of dust (Fig. 378). The only satisfactory sanitary method of dusting is by the use of the damp cloth. This cloth should not be wet enough to leave moisture on the furniture, but damp enough to retain the dust. By means of the cloth all the dust is removed from the room, and may be burnt up with the cloth or otherwise disposed of. Fig. 379 illustrates a condition too common to require comment.

Foods.

Much care should be exercised in the selection, keeping fresh, and cooking of various foods, particularly meats and meat products. In the selection of meats, only such should be accepted as have come from a healthy animal. In the keeping of meats and meat products, it must always be borne in mind that in the processes of putrefaction passed through by such organic foodstuffs, there is not uncommonly produced a virulent poison, known as ptomaine. This is a by-product of the growth of the putrefactive bacteria. This ptomaine is not destroyed by cooking, although the germs which have produced it may be. Flesh, fish, shell-fish, milk, cheese, pies, sausages and the like, are subject to phenomena of this kind. It often happens that whole families or picnic parties are afflicted with ptomaine poisoning as a result of eating spoiled food.

There are certain meats, also, that contain the eggs of parasitic worms, and which if eaten raw or partially cooked will transmit the parasites to man. Trichina, or pork worm, and several species of tapeworms belong to this class. All of these forms, however, are easily killed by the ordinary process of thorough cooking. Certain foods may themselves be fresh and good, yet contain germs of disease through some more or less obscure source of pollution. Milk, for example, may contain germs of typhoid fever, diphtheria, scarlet fever, and the like, if it has been handled by a milkman who has one of these diseases himself, or if even a member of his family has one. Extensive epidemics have been spread in this way.

Milk is a food that receives much filth from unclean cows, dirty barns, dusty stalls, and similar sources, and it sometimes is desirable to kill or check the growth of germs thus gaining access to the milk, particularly if milk is used for children or patients. This can be done by the processes of sterilization and pasteurization. In sterilization, the milk is held at the boiling temperature, 212° Fahr., for thirty minutes. All germs are killed by this process, but the milk acquires a taste

Fig. 378. Moving the dust from one place to another.

disagreeable to many persons, and at the same time is rendered less digestible, particularly for young children. To remedy these two difficulties and at the same time to render the milk safe, it may be pasteurized, that is, heated to 155° Fahr., instead of the boiling point, for the same length of time, and then immediately cooled to about 40°.

Many fruits and vegetables come from unclean sources, having been grown on sewage-fertilized soils, or handled by unclean people, which makes it desirable to have these articles thoroughly washed, if eaten raw; or, better, not to eat such articles raw, but insist on having them cooked. Cabbage, celery and lettuce are often grown on a soil covered with filth, and then eaten raw. Grapes, apples, peaches and other fruits, often sold by foreigners who know nothing about any form of cleanliness, should always be thoroughly washed before being eaten.

All places about the house where food is kept should be scrupulously clean. This is particularly true of the ice-box or refrigerator, where uncleanliness may become the source of disease.

Care of cases of transmissible disease.

It is important to remember that no case of transmissible disease (contagious or infectious) arises unless there has been some preceding case of the same kind. It may not be possible always to see the exact manner in which the contagion has been spread. No case arises without the specific germ, and that specific germ must have come from a person or animal suffering with that same disease. It is evident, if the germs have come from a person suffering with the disease, that in order that germs should escape from this person some one must have been ignorant or careless about caring for the case. When properly cared for, there is no need for the spread of disease from any patient. It is necessary to understand, therefore, something about the nature of the different diseases that come under the class of transmissible diseases. The term transmissible is used because it is difficult to define and draw the lines between the terms contagious and infectious. Smallpox, measles, scarlet fever, scarlatina are among the most easily transmitted of these diseases. Measles is just as contagious as smallpox, and should be treated with the same precaution. Seldom is this done, because measles is regarded as a light and unimportant disease. The disease itself may be less severe than smallpox, but measles often leaves serious after-effects, such as defective eyes or ears or heart. This is true of diphtheria and scarlet fever, and the after-effects are to be dreaded as much, if not more than the disease itself. If any one of these diseases is suspected, it is well to err on the side of safety and take every precaution until the doubt has passed. One should always obey the instructions of the board of health both during and after the time of quarantine, even though such board may not be operative in the particular locality.

When a case of disease, such as measles, smallpox, diphtheria or scarlet fever, arises in the home, the patient should be isolated in a room or part of the house to which no other member of the family except the one who is to care for the patient may have access. This isolation, or individual quarantine, means far more than merely confining the patient to a room. It comprises, in addition, the employment of a separate nurse or attendant, who on entering the room should slip on a gown or its equivalent, which should not be removed while in the room. The physician should be supplied with a similar gown for just such occasions. All excretions and secretions from the patient must be disinfected before leaving the room. All bed and

Fig. 379. An overloaded corner, inartistic, requiring much expenditure of labor, and a perfect refuge for dust.

body clothing must be disinfected at once, and not allowed to stand undisinfected, even in the sickroom. The patient must have separate eating utensils, separate handkerchiefs, towels and napkins, all of which must be disinfected before leaving the sick-room. The dishes and silverware should never be sent down and washed with the eating utensils of the rest of the family, and neither should the clothes and cloths be washed with the laundry of the family, until they have been thoroughly disinfected.

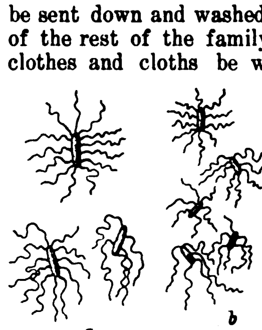

Fig. 380. Two water organisms. (a) Typhoid fever organism (*Bacillus typhi-abdominalis*), with flagellæ over the surface. (b) Colon bacillus (*Bacillus coli-communis*). Occurs in the intestines of animals; common in water contaminated with sewage; produces gas, which the typhoid fever organism does not. After Fischer.

Neighbors should not be let into the house at such times, and under no conditions admitted to the sick-room. The effectiveness of these measures of precaution will depend wholly on the conscientiousness of the attendant and members of the family.

Figs. 380–382 show the water-borne germs of serious diseases. The anthrax bacillus, Fig. 383, may be water-borne. The figures are much magnified.

Disinfecting solutions for use in the sick-room.

A 2 per cent solution of washing soda, made by dissolving one part of soda in fifty parts of water, when applied hot is an excellent disinfectant. Clothing should be allowed to remain in the solution for two hours. Carbolic acid in a 5 per cent solution is excellent for disinfecting sputum, vomited matters and bowel discharges. The solution should be thoroughly mixed with the materials to be disinfected and should remain in contact with them for two or three hours.

If diphtheria is suspected, antitoxin should be used unhesitatingly. If the case does not turn out to be diphtheria the dose will do no harm, and if it is diphtheria, the few hours gained may save the life. The efficiency of the antitoxin as a preventive measure or cure depends on its injection at an early stage of the disease.

If one member of the family has consumption, the greatest care is necessary to prevent its spread to other members of the family. Each expectoration from the patient contains one to five million tuberculosis germs that will be disseminated through the atmosphere just as soon as the sputum becomes dry. Therefore, all expectorations must be received into a cup or vessel containing a disinfectant (5 per cent carbolic acid) to destroy the life of the germs before they become dry. If every consumptive would take proper care of his expectoration, it would not take very many years to stamp out this "great white plague." A person having consumption is not looked on nowadays as incurable; but by conscientiously living and sleeping out-of-doors, eating good nourishing food, not working or getting the body physicially tired, the disease may be completely cured. No one of these factors can be neglected, however, without the disease getting the better of it. Pocket spit-cups have been devised and are exceedingly useful for the consumptive, as a substitute for the unsanitary handkerchief. The contents of these pocket cups can be destroyed by burning or disinfection as often as seems necessary.

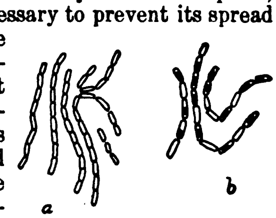

Fig. 383. Bacillus anthracis. The anthrax bacillus. (a) Young growth, showing chains. (b) Older growth, with spores. The spores are carried by the water and frequently infect the pastures subject to overflow. After Fischer.

Typhoid fever germs are spread only through the bowel discharges and urine of typhoid patients. The germs of typhoid fever do not live outside of the human body for any length of time. Consequently, if all the bowel discharges and urine from all cases of typhoid fever were disinfected at once, the disease could actually be stamped off the face of the earth in the space of a year or two. Typhoid is a filth disease. A person having it has more or less directly taken into his mouth some material from the bowel discharge of a typhoid case, either in water or in food material. Typhoid is not spread through the air.

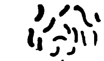

Fig. 381. Asiatic cholera organism (*Spirillum choleræ Asiaticæ*), found in water. The cause of Asiatic cholera.

To prevent the spread of typhoid from a patient, absolute cleanliness is essential first of all; and second, the immediate disinfection of all body discharges. Quarantine is not essential for typhoid fever; but the attention to cleanliness cannot be overdone. Frequent washing of the hands on the part of the person or persons waiting on the sick one must be insisted on. This is for their own protection as well as for other members of the household. The bowel discharges from the typhoid case must never be thrown out until they have been completely disinfected with hot washing soda solution or 5 per cent carbolic acid solution. This applies to any diarrhœal disease, cholera or intestinal tuberculosis, as well as typhoid fever. Sputum from all cases of consumption, influenza (la grippe), pneumonia, bronchial affections, and ordinary coughs and colds should be disinfected at once before becoming dry.

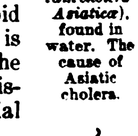

Fig. 382. Same organism showing flagellæ. After Fischer.

Rooms in which cases of smallpox, measles, scarlet fever, scarlatina, chicken-pox, diphtheria or consumption have been confined should be thoroughly fumigated before being occupied by well people. To fumigate, after the room has been vacated by the patient, all cracks and crevices about the doors, windows and fireplaces should be sealed tightly with gummed paper, the door closed and locked, and kept so for at least twenty-four hours. This is to allow all dust in the room to settle to the floor. Then the room is ready for fumigation, the most efficient process being by use of formalin. If a special generator for formaldehyde gas is not obtainable, the commercial formalin (40 per cent formaldehyde) may be simply sprayed about the room. The quantity necessary for disinfection is one pound of the 40 per cent solution for every 1,200 cubic feet of air space in the room. The room should remain tightly closed not less than twelve hours, and preferably twenty-four hours. After the room has been opened up, if the formaldehyde gas fumes remain after complete airing, some ammonia water should be sprinkled about the room, and the fumes of one will counteract the fumes of the other.

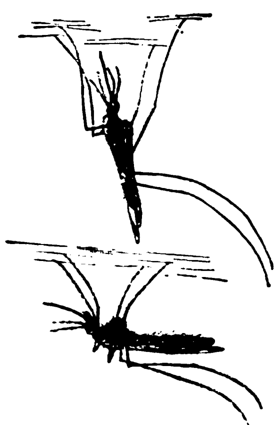

Fig. 384. The malaria mosquito, and the culex that does not transmit malaria. Resting position of culex (bottom) and anopheles or malaria mosquito (top).

Spreading of disease by the common house-fly.

The fly has undoubtedly been the means of spreading disease germs in many cases when the transmission seemed obscure. When it is considered that the breeding-place of the fly is in filth and decaying matter, that it swarms about and feeds on human and animal excrement, that it flies directly from such places to the food in the kitchen, dining-room, or wherever exposed, is it strange that disease results? The hairy legs and bodies of the flies furnish excellent places of lodgment for dirt and filth, and when the fly walks over the bread, jelly or other food, he is literally wiping his feet on these materials. Now, if the discharges from a case of typhoid fever, or the sputum from a consumptive, happen to have been walked over by the fly some time prior to meal-time, it is not difficult to see how the food may become directly infected with the germs of these diseases. It only remains for the person eating such infected food to be in a susceptible condition to become a victim of the disease. To prevent the spread of disease by flies, it is necessary, then, to keep the flies away from the foods and out of the house by careful and thorough screening; to reduce the number of flies by destroying their breeding-places as far as possible; and to disinfect all discharges from the body which can possibly contain the germs of disease, so that, should the flies come in contact with such filth, the vitality of the germs will have been destroyed.

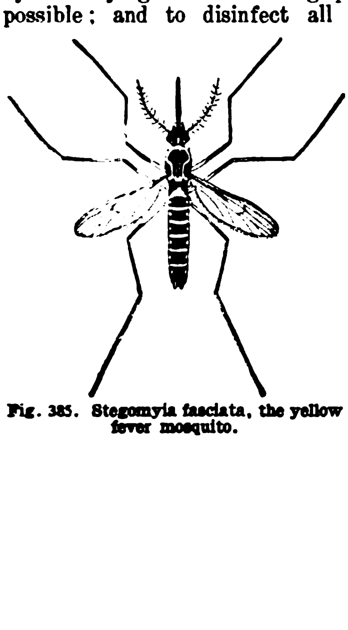

Fig. 385. Stegomyia fasciata, the yellow fever mosquito.

Spreading of disease by mosquitos.

Malaria and yellow fever are spread entirely through the bite of certain species of mosquitos. In the case of malaria, the mosquito, in order to transmit the disease, must be of a particular kind (anopheles), and must have bitten a person some time previous, said person having in his blood the plasmodium or germ of malaria. The germ undergoes certain necessary stages in its life-history in the body of the mosquito. When the mosquito bites a person, it injects into him some saliva containing the germ, at the same time that it sucks out the blood of the victim. Then the germ passes through other stages in the blood of the person bitten, these stages corresponding in a rather definite order to the symptoms of the disease. To prevent the spread of disease by the mosquito, it is necessary to destroy all pools, puddles and stagnant water by careful drainage, and by the removal of all old cans or bottles which may collect water during a rain; to treat breeding-places with insecticides, or to introduce some natural enemy of the mosquito, as the dragonfly, into the breeding pools, such as will devour the eggs or larvæ forms ("wiggle tails"); to cover rain-barrels or other vessels designed to hold water about a house, which may stand long enough for mosquitos to deposit their eggs therein; and to cover carefully with mosquito-netting every patient suffering with malaria. The house should always be well-screened. The screen must be fine enough to keep the mosquito out. The so-called "fly screens" will not keep out all forms of mosquito.

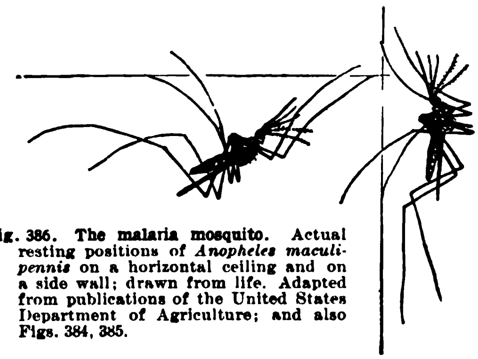

Fig. 386. The malaria mosquito. Actual resting positions of *Anopheles maculipennis* on a horizontal ceiling and on a side wall; drawn from life. Adapted from publications of the United States Department of Agriculture; and also Figs. 384, 385.

To treat a pond or any large body of water with oil, it is best to use what is called "fuel oil" of rather low grade, such as the Standard Oil Company calls "light fuel oil." It is allowed to spread over the entire surface of the water. If the female attempts to lay her eggs in the oil-covered water, she perishes and the eggs perish with her. Small quantities of water, such as are contained in rain-water barrels, small duck ponds, and the like, may be treated with ordinary coal-oil, as large quantities would not be required.

Farm animals in their relation to health.

Every precaution should be taken to keep all animals on the farm in good health. All the sanitary laws applicable to the human animal apply to the lower animals as well. Many diseases may be transmitted from man to the animals, and vice versa.

Hogs and cattle known to be diseased should be killed, and their bodies disposed of in a sanitary manner. Burying such animals is not recommended. The best way is to destroy by burning. The germs of anthrax and tuberculosis may remain alive in the ground indefinitely. Both of these diseases are presumably transmissible to man. Glanders is a disease that is also transmissible, with very serious results in man. Tetanus (lock-jaw) affects both animals and man, and animals suffering with this disease must be treated accordingly. Great care must be used in the disposal of bodies dead of this disease. Dogs, cats and poultry are subject to diseases, many of which produce effects on the human body. Hence, close contact between the animals and the household should be carefully guarded against. It is the sick animal that usually gets the most attention, and at such times comes in very close contact with the interested persons. Absolute cleanliness and the generous use of disinfectants are the recommendations for such instances.

Fig. 387. Pond in pasture, having common forms of algae, blue-flag and bullrush. Not a good water.

THE CONTAMINATION OF WATER

By *L. H. Pammel;*
and a part by *H. L. Russell*

During the last decade a widespread interest has been expressed in all parts of the country with reference to securing sanitary water for drinking purposes. Not only does this apply to water used for human consumption but also to that used for stock. A large number of human as well as animal diseases may be attributed to the poor quality of water. This is true on the farm as well as in villages and cities. The city population is indirectly interested in having a good water-supply on the farm, because contagious diseases, as typhoid fever, diphtheria and scarlet fever, are milk-borne, and at least in typhoid fever the water may be responsible. Epidemics of typhoid fever have been attributed to the use of milk which had come in contact with water containing the typhoid fever organisms. If it is known that typhoid fever has been on the premises of the dairyman, he is indirectly responsible for the conveying of the disease. The colon bacillus, the normal inhabitant of the intestinal tract, is sometimes the cause of poorly defined intestinal disorders. Water may contain the colon bacillus because of the presence of the bacillus in the feces of cattle and man. It is well known that anthrax, hog cholera and other intestinal diseases of the lower animals may be conveyed through drinking-water, and every one of the bacterial diseases is more or less likely to be carried in this way. It is certain that anthrax is thus frequently conveyed. In one case known to the writer, the animals that died of anthrax were buried on the side of a hill. The rains of the following season removed the soil and carried the virulent spores down to the fields below, affecting not only the meadow, but also the water.

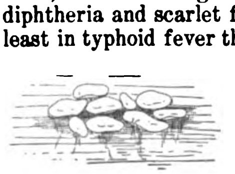

Fig. 388. Duckweed (*Lemna minor*) **floating on water.** Duckweed is common on the water of sloughs and ponds.

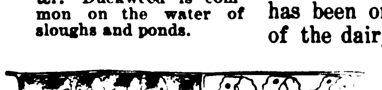

Fig. 389. Two cells of spirogyra. One of the green algæ found in running brooks and streams. The chlorophyl arranged in a spiral band. After Atkinson.

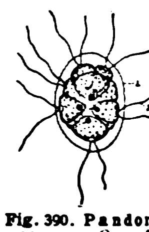

Fig. 390. Pandorina morum. One of the green algæ found in water, sometimes forming water-bloom. (1) Gelatinous membrane. (2) Cilia or flagella. After Pringsheim.

In addition to these well-defined diseases, there are those that are caused by drinking-water that contains impurities from decomposed products of such diseases as hog cholera, swine plague and chicken cholera. Cattle drinking this water may be afflicted with diseases that belong to the type known as œdema, or they may be poisoned with ptomaines. This occurs most frequently when cattle are allowed access to drinking-water from sloughs and ponds.

The farm should have as good supply of water as either the city or village. Usually this supply is not difficult to secure, since there is less opportunity for pollution, especially when there is a large water-shed with few buildings or dwellings. The farm water-supplies come chiefly from the following sources: mountain springs, whose sources are undoubtedly beyond the danger of pollution; lowland springs; streams; irrigation ditches; lakes; ponds; wells.

From a biological standpoint, four sources of pollution must be taken into consideration,—flowering plant contamination, algal contamination, bacterial contamination and animal contamination. Any one of these may result in injury to man or animal.

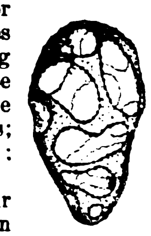

Fig. 391. Clathrocystis. One of the blue-green algæ, the cause of pigpen odor; common in reservoirs during the summer months. After Moore.

Contamination by flowering plants.

The flowering plants usually found in water-supplies are practically harmless, except as they produce, through decomposition, products that may result in what is called stagnant water; but this condition seldom takes place when the surroundings are well kept. In many sections of the country, however, the growth of weeds in lakes that at some time have been low is regarded as not only unsightly, but also as injurious and detrimental to health. The plants that are generally found in these waters are: The fresh-water eel-grass (*Vallis-*

neria spiralis), pickerel-weed (*Pontederia cordata*, *Eichhornia speciosa* [the latter is abundant in the water-supplies of Florida]), the water plantain (*Alisma Plantago*), bullrush (*Scirpus lacustris*), the reed grasses (*Phragmites communis*), species of sedges (Carex, Cyperus, Eleocharis), watercress (Nasturtium), speedwell (Veronica), water weeds, as Potamogeton and *Anacharis Canadensis*, water lily (Nymphæa), lotus (Nelumbium), and duckweeds (Spirodela, Lemna, Fig. 388, and Wolffia).

Fig. 392. Nostoc Linckii. One of the blue-green algæ, forming slimy blue-green masses on rocks in lakes and streams. Large cells to the right are spores, taken from the filament on the left. The clear cell in the filament is a heterocyst. After Atkinson.

Algal contamination.

The interesting group of flowerless plants known as algæ comprises many species, found both in fresh and salt water. The various fresh-water algæ are widely distributed and have been known to cause injury. Some of the salt-water forms are well-known, the so-called sea-mosses being algæ. Some of the seaweeds are used commercially, as, for example, *Chondrus crispus*, from which blanc-mange is made, and other algæ, as the kelps and bladder wracks (Fucus), used in making commercial iodine. The Spirogyra, or water-silk (Fig. 389), a fresh-water alga, is a thread-like organism with many cells, having the chlorophyll arranged in a spiral band. It is a troublesome weed in water-cress beds. The Cladophora, a branched green alga, is also abundant in pools, and is sometimes troublesome in the same way. One of the most common of the green algæ found in fresh water is the Pandorina. (Fig. 390). This often forms green scum on stagnant ponds, making such water injurious to farm stock. It consists of colonies inclosed in a gelatinous membrane, the organism moving about by means of cilia that extend through the membrane. Allied to the Pandorina are other algæ found in similar places, the Pediastrum and the Volvox. In high northern altitudes the "red snow" is caused by an alga known as *Sphærella nivalis*. The green algæ are not so troublesome as the blue-green algæ. It is thought that the green algæ, unless decomposition occurs, are beneficial rather than injurious to the water, as they dispose of many organic substances.

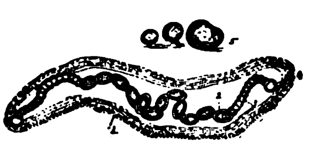

Fig. 393. Nostoc paludosum. One of the blue-green algæ, forming gelatinous masses on rocks. (1) A single filament, surrounded by gelatinous mass. (2) Spore. (3) Vegetative cell (4) Heterocyst. (5) One of the gelatinous masses.

The blue-green algæ are of many different forms. One of the most common is Oscillatoria, found in water-troughs and when water collects on tanks; it consists of many cells joined together in a filament, and multiplies by cell-division. While it is blue-green in color, in a mass it may appear dark, blackish green. One of the most obnoxious of the blue-green algæ is Clathrocystis (Fig. 391). This forms colonies, solid at first, but later becoming perforated. The Nostoc (Figs. 392, 393) forms gelatinous masses sometimes the size of a small tomato, which may be seen floating in the water. It consists of irregular, interwoven filaments inclosed in a gelatinous mass. Related to the Nostoc is the Anabæna, consisting of filaments free or united in a mass. The condition most favorable for the development of the Clathrocystis and Anabæna (Fig. 394) algæ is a warm temperature from June to September. These plants sometimes form scums on the surface of the water or occur as floating masses. They produce what is called the "pigpen" odor, causing the water to be objectionable for domestic purposes as well as very disagreeable, as the odor can be detected at a long distance. There are cases of suspected poisoning from these blue-green algæ, as have been reported by Dr. Arthur from southern Minnesota and northern Iowa. For sanitary purposes, the odor-producing algæ should be distinguished. This odor is due to the production of essential oils by these plants, that impart very undesirable qualities to water-supplies. Herein lies the chief contaminating influence of algæ.

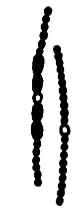

Fig. 394. Anabæna. One of the blue-green odor-producing algæ. After West.

In addition to the green and blue-green algæ, many waters contain diatoms (Fig. 396). These form brownish scums, but are not injurious. The cell-walls of diatoms contain a large quantity of silica.

Bacteria of water-supplies.

The bacterial content of water varies greatly. Statistics show that artesian wells contain fewer organisms and hence furnish a purer supply of water than is found in any other source. In the representative artesian wells in Iowa, it is found that the number varies from 0 to as many as 40 or 50 organisms per cubic centimeter. The reason for the small number is that the water is constantly flowing. Artesian wells from which the water is not flowing constantly contain a larger number of organisms, due to the fact that organisms are brought from the surface in pumping. From a study of the deep wells in various parts of the country, it is found that the number of organisms is generally less than in shallow wells. In the water from a well 2,300 feet deep, supplying the College of Agriculture at Ames, Iowa, there were found 50 to 250 organisms per cubic centimeter (about $\frac{2}{5}$ cubic inch). Frankland found in a Kent county (England) well sunk in chalk 6 to 26 organisms per cubic centimeter. In a deep well at Grinnell, Iowa, the number was 0. In a well near the college at Ames,

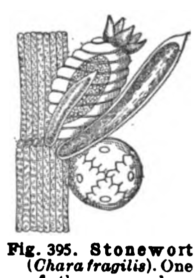

Fig. 395. Stonewort (*Chara fragilis*). One of the green algæ. Part of a filament. It is a large, weed-like plant, often conspicuous in ponds.

114 feet deep, the number of organisms was 14,750 per cubic centimeter, while another well not far distant, at the same depth had only 31 organisms per cubic centimeter. It is evident that in cases where a large number occur there must be a leak in the pipe or a subterranean channel connecting with the source of water-supply. Of course these organisms may or may not be pathogenic or disease-producing, and the mere number of organisms is not a measure of the injuriousness of water; but these and the following statements show how readily contamination may take place.

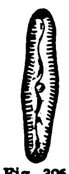

Fig. 396. Navicula. One of the diatoms forming free brown masses in water. After Moore.

Shallow wells are frequently contaminated with a large number of organisms. A certain well at a depth of 40 feet was found to contain 160 to 1,100 bacteria per cubic centimeter. Another well, 10 feet deep, contained as many as 8,000 bacteria per cubic centimeter. Large open wells that have not been used are frequently contaminated, though these wells may be 40, 50 or even 60 feet deep. In many shallow wells the colon bacillus and acid-producing species occur. It should be mentioned in this connection that it is difficult to make any exact statements as to the number of microorganisms and extent of sewage contamination in the water in shallow wells, because conditions frequently change. In the case of deep wells the question is very different, since they are not subject to such frequent fluctuations.

Rivers usually contain a large number of organisms. The Skunk river, an Iowa stream, in February contained 1,500 to 1,900 bacteria per cubic centimeter. The Des Moines river in March contained 1,200 to 1,400 bacteria above the sewage outlet, while below it contained 7,770 to 87,500 organisms per cubic centimeter. Frankland states that in one instance the river Ure, in York county, England, contained 1,800 bacteria per cubic centimeter above Ripon, while below it contained 33,400 bacteria per cubic centimeter. Other figures might be added to show the farmer the importance of disposing of the sewage in some other way than by dumping it into the rivers. The water of many streams is rendered unsafe because of such pollution. The farmers utilize the water from these streams, and when such water is used disease of some kind is likely to follow.

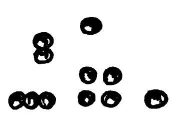

Fig. 397. Staphylococcus pyogenes. Common pus organism sometimes found in water.

Certain mountain rivers, examined by the writer in 1905, had organisms varying in number as follows: Gunnison river, 1,750 to 1,820 organisms per cubic centimeter; Arkansas river, 28,000 to 45,500 organisms per cubic centimeter. This water was extremely muddy. The Mississippi river contained 2,000 to 9,600 or more; Green river, Washington, contained 28,000 to 32,000 organisms per cubic centimeter.

That germs may be carried a considerable distance is seen by the fact that typhoid fever organisms may live for several weeks in river water. Investigators found that typhoid fever organisms were still alive in dilute sewage after sixty days; in unsterilized sewage they did not live longer than fourteen days. A common red organism, known as *Bacillus prodigiosus*, may be carried many miles in water, as demonstrated by Mr. Kirchner, who emptied a 40-gallon broth culture of this organism below Grafton, Ill., and found it twenty-five miles below the point of introduction.

Spring water, though often said to be pure, is only found in this condition when springs have their origin in mountain regions. In a prairie country, the spring water, unless protected from surface washings, is frequently contaminated by surface drainage, especially when cattle have access to the spring.

Iowa spring waters show that the number of bacteria per cubic centimeter varies from 140 to as many as 5,800. The water from the spring in which 140 bacteria per cubic centimeter were found was protected from surface washings by brick-cased walls, and was covered. The other springs were open and surrounded by herbage of all kinds. Springs protected from surface waters contain a much smaller number of organisms. They may be comparable to deep or artesian wells. Cramer found in springs in Zürich that the number of organisms varied from 9 to 45. A spring investigated by the writer on the North Yakima river, Washington, contained 104 to 220 organisms per cubic centimeter. A spring in a dense forest near Creighton, Oregon, contained 1,200 to 1,500 bacteria per cubic centimeter. This was an open spring surrounded by herbage and decomposing leaves.

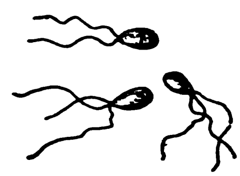

Fig. 398. Bacillus fluorescens. A common organism found in water. Produces fluorescent pigment. Flagella are found at the end of the rod. After Fischer.

It is said that fresh-water lakes contain fewer germs than river water. In Lake Zürich there was found, from October to December, an average of 184 organisms per cubic centimeter. Many other European lakes, however, show a much larger number. Near the shore-line of this lake there is said to have been found 16,000 bacteria per cubic centimeter. In Lake Washington, near Seattle, close to the shore the writer found 16,000 to 20,000 bacteria per cubic centimeter.

Railroad water-supplies need attention, for the farmer is deeply interested in the purity of the water supplied to his stock by the railroads when shipping. When the wells are deep and water is constantly pumped, there is very little danger from contamination. On the other hand, when shallow wells are used and when they are in close proximity to the stock-yards, contamination is certain to occur. In a number of railroad wells between St. Paul, Minnesota, and Billings and Miles City, Montana, there was found an unusually good supply of water. The number of organisms in wells at Billings varied from 2,450 to 4,200, and at Miles City from 80 to 2,450. An investigation of railroad water-supplies in Iowa showed some wells to be contaminated with the colon bacillus. In most cases the colon bacillus was absent and gas was not formed. In a few instances, however, the colon bacillus and acid-producing species were abundant. The presence of the former indicated contamination with excreta. Such water frequently causes disorders among stock in shipping.

A further discussion of water bacteriology.
(By H. L. Russell.)

The bacterial content of water is primarily dependent on the germ content of the soil. The upper layers of the soil abound in germ life, the amount of which depends on the nature and origin of the organic matter present. The processes of decomposition that are continually operative in these layers suffice to seed the upper strata richly with these lower forms of life, and, as suitable and sufficient food is present, a marked development occurs. While this condition obtains at or near the surface, the germ content diminishes rapidly as the depth increases, so that the soil a few feet deep is practically free from all kinds of organisms. As water falls through the air in the form of rain, hail or snow, it collects many floating particles, including bacteria. When it reaches the earth, it either percolates into the soil or flows over the surface of the ground. In the latter case it becomes highly charged with soil bacteria, and, as a consequence, the water in streams, rivers and even lakes is relatively rich in these organisms. Naturally, the germ content bears a more or less definite relation to the load of sediment held in suspension. Streams that are turbid by reason of high water, or because of the character of the soil, have a much higher bacterial content than clear water streams. When the load of silt is deposited, as in a sluggish stream or lake, the germ content rapidly decreases.

The water which percolates into the deeper soil layers has its initial content largely removed by mechanical means. Conditions are also unfavorable for the development of life. Therefore, by the time it reaches that underground water reservoir known as the ground water-supply, it is generally free from all kinds of organisms, and is markedly different from a surface supply, so far as its biological character is concerned.

When this practically sterile ground water is tapped, as in a well, opportunity for bacterial infection is sure to occur. The drilling of the well introduces organisms from the outside, but these soil forms do not thrive long in water, and in the course of a few months nearly all of them disappear except those species that are distinctively adapted to these surroundings. This is particularly true when the well is much used, as the process of pumping draws on the supply of germ-free water in the soil. This condition results in the bacterial content of properly constructed wells being low, while in the open dug well it is usually higher, even though no external contamination of a dangerous kind may have occurred. Springs also have a relatively low bacterial content because of their origin from the soil water. The differences, therefore, that exist in normal surface streams and unpolluted subterranean waters are so marked that a bacteriological examination aids materially in determining whether or not a supposedly unpolluted water is contaminated with surface drainage.

The problem of water bacteriology is to recognize those forms of bacteria that are detrimental to man and animal life that are disseminated through the medium of water. The types of disease-producing organisms that are spread in this way are those that find a suitable location for development in the alimentary canal. Water becomes polluted with these organisms generally through the dejecta, in some cases by means of the liquid as well as the solid excreta. Surface waters, therefore, are very much more likely to be infected than those of subterranean character, unless the opportunity for the introduction of surface drainage exists.

Fig. 399. Poor location for well.

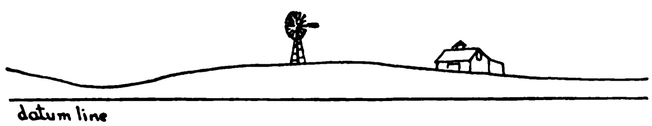

Fig. 400. Good location for well.

Typhoid fever and cholera are unquestionably the most important diseases of the human type that are spread in this way; anthrax, hog cholera, and other intestinal diseases, the leading ones among stock. It is exceedingly fortunate that most intestinal diseases of this class are confined in the main to one species of host. Thus, hog cholera and swine plague affect only swine, while typhoid fever and cholera are confined to the human. Anthrax assumes an intestinal form in animals, but in man it is localized generally as a malignant pustule. For this reason, the possibility of interchange of disease between man and varying kinds of stock is materially lessened.

The recognition of these specific disease-producing organisms in water is attended in some cases with especial difficulty. This is due in part to the fact that most organisms of this class do not find favorable growth conditions in water, especially when it does not contain a large amount of organic matter. It is largely, then, a question as to how long the disease bacteria can retain their vitality in such a medium. Various factors are more or less effective in hastening the death of these dangerous organisms. The germicidal influence of direct sunlight, the lack of suitable and sufficient food supplies, the antagonistic effect of the by-products formed by the inherent soil and water bacteria, as well as the effect of dilution and sedimentation, are all factors which tend to shorten the vitality and reduce in numbers the disease-breeding species.

Naturally those forms unable to produce spores succumb more readily than spore-forming types. Anthrax is perhaps the most persistent of any of the more dangerous species.

The detection and recognition of harmful species rests on the application of special technical methods, but these are rarely used in ordinary sanitary surveys. In the present state of water bacteriology, much more effort is spent on the detection of abnormal conditions than in the actual isolation of the disease types themselves. The shortened lifetime of most disease-producing forms in water, and, consequently, their probable disappearance before suspicion against any water-supply is aroused, the inherent difficulties in their recovery, especially when present in limited numbers in comparison with the native water forms, makes the discovery of such types exceedingly difficult, except under special conditions. It necessarily follows in most cases that organisms of disease that are spread through the medium of intestinal dejecta will be associated with the common intestinal bacteria, and, inasmuch as these organisms are usually much more abundant and can be much more readily isolated, it is customary, in making a sanitary examination of a water, to subject it to those tests which will determine the presence of such sewage or fæcal forms.

Treatment of water. (Pammel.)

It may be said that it is possible to reach a safe conclusion as to whether water is good for potable purposes only by making special examinations at different times during the year. Every farmer should see to it that his well is located some distance from the barnyard. The water used for stock should be pumped into a reservoir which leads into a clean tank. Ponds should not be used unless the stock is prevented from going to them. When water from ponds is used it should be let out into a water-trough. When possible, deep wells should be used in place of shallow ones. In order to prevent the growth of algæ and bacterial organisms, water should not be allowed to stand for any great length of time.

In many cases, water is so charged with algæ and other organisms that it becomes necessary to remove them. This can be done by gathering the larger forms in drag-nets. Certain fresh-water algæ, as Spirogyra, are extremely sensitive to copper sulfate solution. This plant is destroyed by a mixture of one part of copper sulfate to 25,000,000 of water; water scum (*Anabæna flos-aquæ*), by one part of copper sulfate to 10,000,000 of water; one of the common diatoms (Navicula), by one part of copper sulfate to 15,000,000 of water. Bacteria like Beggiatoa, are destroyed when the proportions are one of the copper sulfate to 100,000 of water. At ordinary temperature, one part of copper sulfate to 100,000 of water destroys the typhoid fever and cholera organisms.

It is not likely that any harm will result from using water that has been treated with copper sulfate in the proportions given above. An eminent pharmacologist writes that when he was asked by a city official to give an opinion as to whether one part of copper in 1,000,000 parts of water would be harmful, he replied: "Assuming for purposes of argument that the copper remains in solution and is not deposited or rendered insoluble, this small quantity could not be harmful to persons even if they drank such water for a few days, since ordinary food, as bread and meat, contains 2 to 3 parts in the million. Some tissues, like the liver, contain as high as 30 parts in the million." And Moore and Kellerman conclude, "There is no authenic record of fatal copper poisoning, and many of the best authorities do not consider copper a true poison; they hold that it is a natural constituent of the body, and in minute quantities has no effect on man."

In the treatment of water, prevention is much better than cure; that is, every effort should be made to remove all sources of contamination. Understanding what the sources of pollution are, the farmer has the matter in his own hands.

THE INSTALLATION OF FARM WATER-SUPPLIES

By *Henry N. Ogden*

Farmers have paid little attention to the needs of the house in the matter of water-supply. For the needs of the stable, or in order to economize in the regular farm work, every effort has been expended to make improvements,—to secure all the labor-saving machinery of the latest pattern, and to have the stables meet all the requirements of modern hygiene. On the other hand, after a well has been dug somewhere in the yard from which, perhaps at great effort, water may be had, it has been assumed that the house is fully provided for. On some farms, the well may be found on the back porch or in the woodshed, which lessens the exposure but still involves pumping and carrying. Happily this condition of things is passing away, and on the farm, as in the city house, it is now understood that running water in the kitchen sink as well as at the barn, is simple economy; and not a few houses have water-closets and bathroom provided with all modern fixtures.

It is the purpose of this article to consider the question of farm water-works under four heads; (1) the quantity of water needed in the average house; (2) the quality of various sorts of water and their relative value; (3) methods and cost of installation of water systems; (4) methods of disposal of the fouled water.

Quantity of water.

It has been said that the civilization of a community can be estimated by the quantity of soap that it consumes; and it is almost the same thing to say that the refinement of a household is measured by the quantity of water it uses. The poorer and more degraded a household, the less the water used; and the more luxurious it is, the greater the demands for an unlimited supply of water in the kitchen, laundry, bathroom, and about the yard.

It is necessary to know the standards of living, as well as the number of persons in a house, in order to estimate correctly the water used. This may be made clear by quoting some records of water consumption in Boston and Worcester:

	Gallons per head per day
Highest cost apartment houses in Boston use . . .	59
First class apartment houses in Boston use	46
Moderate class apartment houses in Boston use . .	32
Poorest class apartment houses in Boston use . . .	17
Best class of houses in Worcester use	23
Good class of houses in Worcester use	20
Cheaper houses in Worcester use	16
Cheap houses in Worcester use	12
Average of all houses (metered) in Newton use . .	26
Houses with one kitchen faucet only in Newton use .	7

These records show that the quantity of water used per head per day varies from seven gallons, when there is only one faucet in the house, to fifty-nine gallons in the most fashionable city homes. Probably with the ordinary amount of plumbing, viz., hot and cold water in the kitchen and in the laundry, and a bathroom completely furnished, the average consumption of a family may fairly be taken at twenty gallons per head per day. It is to be noted that this is the average quantity used through the twenty-four hours, this being a convenient way of describing the amount. Practically, it is all used in twelve hours, and it is a common practice to assume that the rate at which the water is used during the day is twice that of the daily average. This is important, for instance, if water has to be pumped and the size of the pump or of the piping is being determined, as will be seen later.

There is still another factor that affects the quantity of water, viz., the daily and seasonal variations. Through the summer months, more water is used than in winter, and on some days in the week, for example on wash-day, more is used than on other days, so that it will be wise to provide for a possible rate of flow of 50 per cent in excess of the twelve-hour average. The computation for quantity would then be as follows, assuming ten persons in the house:

	Gallons
10 persons at 20 gallons per day	200
200 gallons in 12 hours equals in 24 hours .	400
Add 50 per cent for excess on certain days and hours	200
Total maximum rate per day . . .	600
Total maximum quantity per day . .	300

This is approximately ten barrels, and would require a tank about four feet square and three feet deep for the day's supply. This doubtless seems large, and, of course, it is more water than would be used when it all has to be pumped and carried by hand; but with faucets and other fixtures it is not excessive, and this quantity should be provided.

The quantity of water required for stock depends on many considerations, such as kind of food, nature of work, season of year and size of the individual. In summer a working horse requires about a gallon per hundred-weight of flesh per day when fed hay and grain. Cows require ten to fourteen gallons per day; steers, eight to twelve gallons; pigs, one to three gallons; and sheep, four to six quarts.

Quality of water.

The quality of a water is, of course, only definitely known by chemical or other analysis, and yet common-sense will be of great service in aiding one to choose a proper source of water-supply. No water is perfectly pure, nor is it best for man to use chemically pure water, for certain salts and metals in solution are necessary for the human body. On the other hand, there are some kinds of pollution that are undesirable and even dangerous. The most common forms in which this infection comes are lime or magnesia, which make the water hard. There is no danger in drinking hard water, so far as medical knowledge goes, although a person accustomed to soft water will probably suffer temporary discomfort on changing to the other. The chief objection to hard waters is in the large amount of soap needed with them, the disagreeable effect of such waters on the skin, and the deposits formed by precipitation in cooking or in the laundry. Other things being satisfactory, therefore, a soft water not affected by lime or magnesia is to be preferred.

Fig. 401. A not uncommon condition,—the family well near a stagnant pond. The bacteria may act on the water during its passage through the soil, giving it the appearance of pure water. This water is unfit to use.

Unfortunately, there are other things that cause pollution of a worse sort. Such pollution usually is associated with human habitations and is the result, in one form or another, of human life. Surface waters, such as brooks or ponds, are most likely to be contaminated in this way, and fortunately the contamination can usually be recognized by even the most casual observation. If the brook flows through bottom lands, where cattle are pastured or where cultivated lands are manured, or if the brook receives the drainage from houses and barns, the quality of the water inevitably suffers. Mere contamination by animal wastes, however repulsive esthetically, may not in itself be dangerous; but if the drainage comes from diseased men or animals, the water may become a carrier of the disease and so cause severe epidemics. For this reason, it is wisest to avoid surface water that may at any time be exposed to animal or human contamination. Fig. 402 shows a source of contamination which resulted in 1,000 cases of typhoid fever in Lowell, Mass.

It is not easy to pronounce on the probable pollution of wells, and they are therefore the most dangerous sources of water-supply. If deep, they may furnish water which is merely hard. If shallow, drainage from privies or barnyards may make them sources of disease or death. Nor is it possible to pronounce, by inspection of the surroundings only, on the probable purity of the water. If they

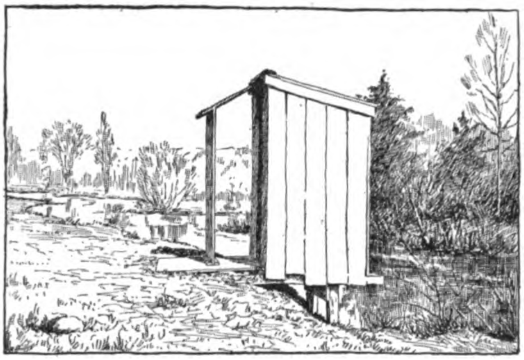

Fig. 402. A too common source of water contamination. The water-supply contaminated from this privy resulted in 1,000 cases of typhoid fever in Lowell, Mass.

are dug through a bed of clay with all opportunity for water to wash in over the top avoided, the water is probably good; but if they are entirely in gravel, not far from a privy or drain, the purity of the water would be very doubtful. Exemption from a serious disease for a period of years does not mean that a certain well water is pure, because the specific cause of a disease may not have been in the water; but if the conditions are such that a disease may be passed from a privy through the water-supply back to the household, sooner or later it it will be done.

Methods and cost of installation.

Gravity.—The simplest and best method of supplying a house is to pipe the water from a spring or brook at a point high enough to permit the water to flow freely from the house faucets. If from a spring, the quantity must be examined. This can be done by measuring, in pailfuls, the overflow of the spring. Not considering the water needed for the barn, it has been shown that a flow at the rate of 600 gallons in twenty-four hours is needed for a family of ten,—a flow at the rate of about two quarts per minute, or five minutes to fill a ten-quart pail. If this is just the product of the spring, there is enough water, but it may be thought that the flow is too slow. Then a tank may be built in the barn or attic of the house, into which water may run regularly, to be drawn out irregularly at greater rates. If the flow at the time when the spring is lowest is found to be as large as necessary, it need only be dug out, walled up and covered. Wood will answer for this, but brick, stone or concrete is more permanent. The relative elevation of the spring and house must be carefully determined, in order to make sure that the water will flow at the highest point desired. It requires a certain force to keep the water moving through a small pipe, and the following table shows the number of feet necessary for this purpose alone. The spring would have to be as much higher than the highest fixture is as shown in the table, in order to provide the pressure required to overcome the friction in the pipe:

Flow in gallons per minute	Head in feet lost by friction in each 100 feet of length	
	½ inch pipe	1 inch pipe
0.5	4	
1.0	7	0.3
2.0	17	0.7
4.0	54	1.6
7.0	140	5.3
10.0	224	9.3

This table shows that it is important to proportion the size of the pipe to the head available. For example, suppose the spring is 50 feet above the highest faucet, and that the flow is to be sufficient so that a bathtub of water can be drawn at the rate of four gallons a minute. Then if the pipe line is 1,000 feet long, the half-inch pipe would be out of the question, since it would take over 500 feet elevation to get that quantity of water through the pipe, and the pipe would not stand that pressure even if it were available. The inch pipe, on the other hand, needs but 16 feet to make the water flow at the rate given.

If the source of supply is to be a brook, the purity of which has been established, it will be sufficient to lay a pipe into the brook and protect the end by a strainer, care being taken to tamp the dirt back well in the trench in which the pipe is laid. It may be that the brook runs dry in the summer time and storage of the spring floods is necessary. This may be done, under certain conditions, as follows: Suppose the length of time during which the stream may be dry is fixed at one hundred days; then the storage supply must be 300 times 100, or 30,000 gallons. In order that the water shall not become stagnant and offensive, the pond or reservoir in which the water is stored must be at least ten feet deep after this quantity has been drawn off. This requires, for economy, a narrow gorge or gulley in which to construct the reservoir.

If a suitable site can be found, its fitness may be tested as follows: Take the average width of the gulley, suppose it to be 20 feet, and multiply that by the length of the pond to be formed, supposing that to be 200 feet. The area of the pond, then, with a ten-foot dam, would be 4,000 square feet, or 4,000 cubic feet for one foot depth. The storage of 30,000 gallons, or 4,000 cubic feet, will then require one foot extra depth for actual consumption. But evaporation from the surface will take place rapidly during the summer months, and it will be necessary to have about 18 inches additional for this purpose, or 2½ feet (above the 10 feet) in all. Such an arrangement may enable one to use a brook, dry in the summer, as a source of supply throughout the year.

The method of constructing a dam for the reservoir described above will depend on the soil, the money available, the permanence desired and the opportunity for overflow. If the bottom and sides of the gully are rock, a rough stone or concrete dam about 12 feet high, designed to allow the water to pour over the top, would be suitable. It should be at least 6 feet thick at the bottom, 2 feet thick at the top and, if logs or ice are likely to be brought down in the spring freshets, should have an oak timber bolted into the top to prevent injury to the masonry. Fig. 403 shows a cross-section of such a dam. If the banks are firm gravel or sandy loam, an earthen dam, 6 feet wide on the top and sloping 2 horizontal feet for each foot vertical, both up and down stream, will be suitable. The ordinary field stone picked up on the farm may be dumped year after year into the brook at the point where it is desired to form the dam, and the result will be a solid structure, which, if not tight at first, will soon become so from the accumulation of fine silt that will wash into the pile of stones. It may be made tight at once by planking the up-stream side. Fig. 404 shows a common stone dam holding a small reservoir that supplies a barn and residence. The pipe is ¾-inch, and is built into the wall near its bottom.

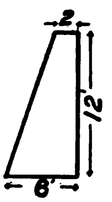

Fig. 403. Cross-section of a rough stone or concrete dam that may be used in gullies, the sides and bottoms of which are of rock.

The earth dam is best made with a core wall, a thin stone or concrete wall, 18 inches thick, running in a trench well down into the foundation and extending along the center of the dam well into the banks on each side. In Fig. 405 is shown a cross-section of an earth dam with core wall. A loose stone dam would have the same cross-section, but would not have the core wall. If the core wall is not built, special care must be taken to tamp the dirt well and to avoid any possibility of erosion by water flowing over the top. The question of overflow is very important, for if a flood comes over the top of such a dam it is almost certain gradually to eat it all away. If possible, then, the overflow of such a dam should be taken around the dam in a new channel cut through the solid bank sideways, either back into the same stream or into another valley; otherwise a special provision for the waterfall must be provided. This may consist, if there is a core wall, of paving with cobblestones up and down both slopes a sluiceway for the running water. This paving must be well laid, the stones well set into the bank and the sides as carefully protected as the bottom. The size of the opening left for the flood water may be roughly calculated from the old rule to make the opening two feet deep and three feet long for every 100 acres of the area draining to the reservoir.

Timber also may be used for the dam and to form the sluiceway. However, unless the timber is to be always under water, it will decay in a few years, so that unless both labor and material are very cheap,

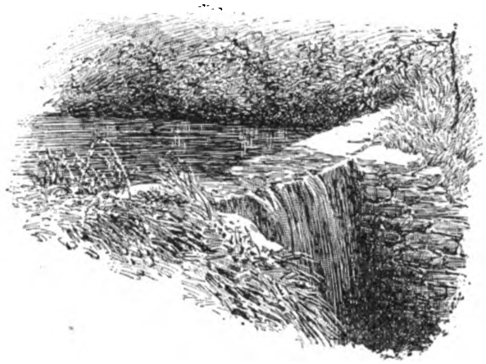

Fig. 404. Dam for a small water-supply.

it is more economical in the long run to use masonry or earth.

The line from the spring or reservoir to the house may be of iron pipe, lead pipe, wood pipe or sewer pipe. If the height of the spring is 100 feet above the highest fixture, then a three-fourths-inch pipe would be sufficient; and this is the smallest that should be used in any case. If, however, there is a fall of only ten feet, the pipe should be larger, and it may be that a sewer pipe four inches in diameter can be used to advantage. Wood pipe made of bored logs was used in years gone by, but now it costs more than iron pipe. If the ground slopes gradually from the spring at the start, then the sewer pipe is particularly well-suited. It can be bought for about six cents per running foot, the same price as three-fourths-inch wrought pipe. If the joints are carefully made with good cement and the earth well-tamped back around the pipes, it will stand an internal pressure of about twenty-five pounds per square inch, and, with care, it might be used for an entire line; but it is always safer to have the lower end, where the pressure is highest, of iron. Lead pipe three-fourths-inch in diameter costs about ten cents per running foot, and is now rarely used.

Well supplies.—Wells may be artesian, deep or shallow. Artesian wells are those that reach a porous stratum, passing through an impervious stratum, the water being held under such pressure

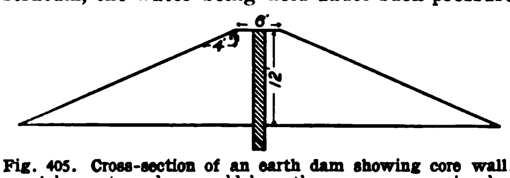

Fig. 405. Cross-section of an earth dam showing core wall. A loose stone dam would have the same cross-section but would not have the core wall.

that it rises to the surface in the well pipes, often with force enough to flow into the residence. Such wells are bored in most instances. Deep wells are similar except that the water does not reach the surface and has to be pumped, sometimes from extreme depths. Shallow wells are driven, or merely dug, into an underground stream, the water from which is raised by simple pumps. In Fig. 406 is illustrated the condition of the ground under which each kind of well is formed.

Rams.—If a fall of water is available, its power may be used to work a hydraulic ram (Fig. 407),

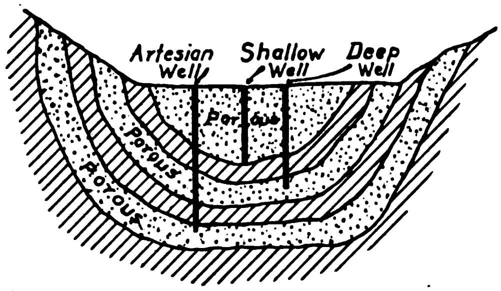

Fig. 406. The condition of the ground under which artesian, deep and shallow wells are formed. The cross-hatched areas are impervious.

and this gives as cheap a supply as gravity, since the occasional care required is very little, and the fall of the water does all the work. The two disadvantages are, (1) that the fall is not always available at the right place, and (2) from accumulation of air in summer and from the formation of ice in the winter, the ram is subject to interruptions. In winter the ram may be kept from freezing by housing it and providing a small coal fire for the coldest weather.

The following table gives data as to size, capacity and cost of hydraulic rams:

Size	Flow of spring per min.	Drive	Dis-charge	Water pumped per min.	Cost of ram
No. 2 . . .	1 gal.	¾	⅜	⅐ gal.	$6 00
No. 4 . . .	5 "	1¼	½	1 "	8 00
No. 6 . . .	20 "	2½	1	3 "	15 00
No. 10 . . .	50 "	4	2	7 "	35 00

This table is based on the assumption that the length of discharge pipe is not over 100 feet, and that the head against which the ram works is not over five times as great as the fall of the stream. The drive pipe should always be made as short as the conditions will permit.

Windmills.—The frequency of winds of sufficient force to turn a mill varies in different localities, but it is probable that in any part of the eastern states five or six days might pass without a wind of any value. Therefore, the tank into which the water is pumped should be large enough to hold about a week's supply, or 300 x 7 feet, or 2,100 gallons, besides the water needed for the stock, say, 4,000 gallons or 500 cubic feet. This requires a tank 8 feet cube, or 10 feet diameter and six feet deep. Then, since the wind, when it does blow, may not be strong or may last only a short time during which the tank should be filled, the mill and pump should be of good size. A 12-foot mill should fill such a tank in about four hours, the pump working at the rate of eighteen gallons per minute. It would be foolish indeed to install a windmill, pump and tank, only to find that in hot weather, when an abundant supply of water is particularly necessary, no water could be had from lack of wind. [For further discussion of windmills, see Mr. Rayner's article, following; also the account of Farm Motors in Chapter VI.]

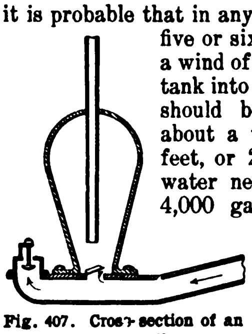

Fig. 407. Cross-section of an ordinary hydraulic ram.

Power pumps.—Perhaps the simplest kind of pump worked mechanically is a well-constructed hot-air engine (Fig. 408), which is made to go by the expansive force of hot air. The fuel may be wood, coal, kerosene oil or gas. Such a pump needs almost no attention after starting and occupies very little floor space, so that it may be placed in a corner of the cellar. [See account of Farm Motors in Chapter VI.]

The following table gives data of sizes, capacities, cost, etc., of the engines commonly used:

Diam. of cylinder	Size of pipe	Fuel consumption per hour			Capac'y in gals.	Cost
		Gas cu. ft.	Keros'e qts.	Coal lbs.		
5 inch	¾	13	½	2	150	$100
6 "	1	16	¾	3	300	140
8 "	1¼	20	1	4	500	175
10 "	1½	50	2	5	1,000	250

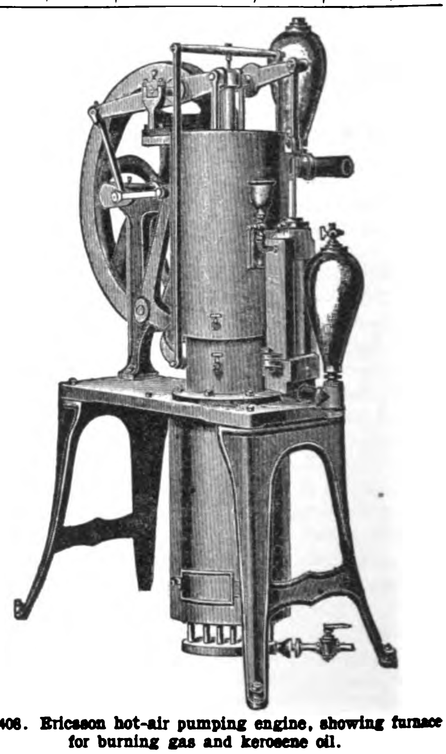

Fig. 408. Ericsson hot-air pumping engine, showing furnace for burning gas and kerosene oil.

If electric current is available, either by purchase or by employment of the force in a waterfall somewhere on the place, it may be used conveniently and satisfactorily to run a pump and motor. It is not possible to give any estimate of the cost by this method, since the conditions would all have to be assumed, and the value of the estimate would be almost useless for any particular installation.

Finally, the most elaborate method of pumping is to install in connection with a steam boiler, presumably used for other purposes on the farm, a regular steam pump, a small Worthington Duplex, for example, that can be operated as needed whenever the boiler is fired up.

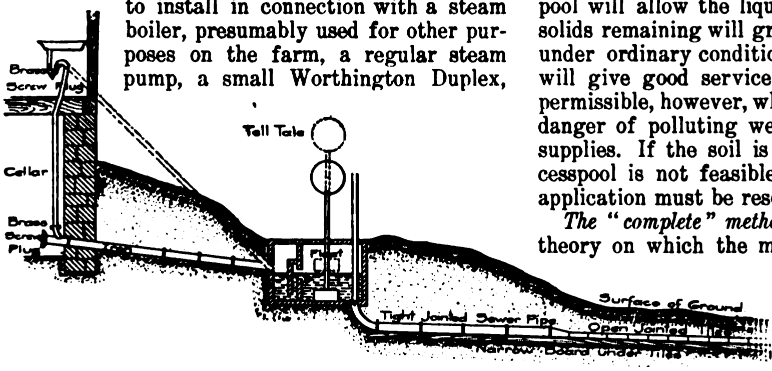

Fig. 409. Disposal of sewage. The sewage from the kitchen passes to the receiving tank, from which it is discharged at intervals into the drains.

Pumping is to be resorted to only when there is no possibility of securing a gravity system. This is true for two reasons: (1) Daily charges for maintenance are very likely to represent a large amount of capital invested. For example, if the cost of pumping were only ten cents per day for fuel, not considering the labor, it would amount to $36.50 a year, which at 5 per cent is the interest on $730. It would be $200 cheaper, therefore, to borrow $500 at 5 per cent to pay for a gravity supply than to pay $30 for a pump that costs 10 cents a day to run. (2) Another reason for preferring a gravity-supply is its greater reliability. The best machinery may break down even under expert care, and the probability is that there would be many days when, with pumps, the house would be without water.

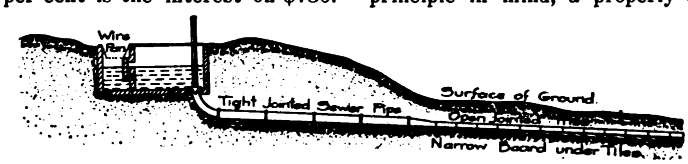

Fig. 410. Intermittent discharge through a wire pan.

Disposal of waste.

The problem of properly disposing of the polluted water grows more serious the more water is used in the house. When the water is brought in pailfuls from a well, the very doubtful practice of throwing the dirty water out the back door on the ground is commonly followed. Some better method should be devised, and when the water runs in streams from kitchen, laundry and bathroom, a better method becomes a necessity. The simplest outlet is into a running stream, but this, too, is not to be advised, even when it is known that the water is not afterward used by some neighbor for drinking or for watering stock. But in case it is used, the volume of stream flow in the driest months should be at least forty times the flow of the sewage turned into it.

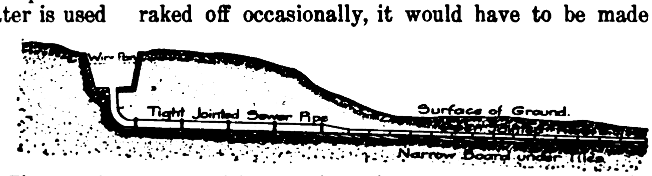

Fig. 411. Methods of receiving and discharging sewage. In this section, the sewage passes continually from the receiving tank into the drain pipes. In Fig. 409, which is the better, the discharge is intermittent.

Cesspools.—If the ground is sandy or gravelly, a cesspool may be made. This should be about 6 feet inside diameter and 8 to 10 feet deep, walled up inside with stones without cement. Such a cesspool will allow the liquids to leach away, and the solids remaining will gradually be liquefied, so that, under ordinary conditions, a cesspool of this sort will give good service for many years. It is only permissible, however, when there is not the slightest danger of polluting wells or other drinking-water supplies. If the soil is heavy clay or clay loam, a cesspool is not feasible and some sort of surface application must be resorted to.

The "complete" method of sewage disposal.—The theory on which the method of complete destruction of injurious sewage depends, is that organic matter—that part of the sewage which decomposes and becomes offensive—is in course of time converted into mineral salts through the agency of bacteria. Of these bacteria, there are two kinds concerned. One, working in the dark, liquefies all the solid matter, such as paper, banana skins, and the like, making the sewage simply a dirty-looking liquid; the other acts in the presence of light and air to clarify and oxidize the liquid, making it clear and bright. Both kinds of bacteria are always in the sewage, and require only proper surroundings to go to work. With this principle in mind, a properly designed treatment will include a closed dark tank of a capacity about equal to the day's flow of sewage, in which tank the required liquefaction may take place. This tank is usually built under ground to keep it warm, and the sewage flows continuously in and out. The remainder of the process may take place by allowing the effluent from this tank to flow slowly through artificially prepared beds of sand three feet deep and of sufficient extent so that there is a square yard for every fifty gallons per day, or for 300 gallons a bed eight feet square.

Since the bed would need to have the surface raked off occasionally, it would have to be made in duplicate so that one bed could always be in use. The two beds should be underdrained and the outflow led away into any natural drainage. It would be better in a northern climate to build a light wooden roof over these beds, which would themselves be below ground, but this is not necessary, as such an arrangement is often used all winter, as far north as Albany, by running furrows through the beds to concentrate the sewage instead of letting it run over the bed in a thin sheet. Instead of building artificial beds, a piece of lower ground 200 to 300 feet from the house may be used to receive the effluent of the tank. Over this the sewage would run between the beds in furrows about four feet wide, or even slowly in a thin sheet over the surface of grass land. If the appearance of the sewage is considered objectionable, the flow may be taken into small agricultural drains, laid twenty feet apart on a grade of about four inches to 100 feet, in which case the sewage will leach out between the pipes and be purified in the soil. The bacteria concerned are chiefly in the top soil, so that surface furrows or surface overflows are best; but if the drains are not more than twelve inches below the surface good results will follow, even in the coldest weather.

In all cases in which the preliminary tank is used, it must be observed that, while not necessary, it secures much better results to introduce directly below the tank a receiving tank which operates at certain intervals, so that the sewage may be discharged on the beds or ground intermittently instead of in a more or less continuous small stream. The reason for this is that if the sewage trickles out on a bed it is absorbed immediately by that part of the bed nearest the inlet and the other parts are not reached. On the other hand, if the flow comes out on the bed once a day, with a rush, the whole bed is covered, every part does its share and no part is overburdened. This reasoning holds true equally with furrows or with grass or with subsoil pipes. If the first tank holds one day's supply, 300 gallons, it should be about 5 feet long, 3 feet wide and 5 feet deep, the extra depth being given to allow deposits to take place. The intermediate tank might be circular, 4 feet in diameter and 4 feet deep. This tank may be provided with an automatic discharging siphon so that the tank will discharge itself whenever it gets full, or it may have a simple flat valve that can be lifted by hand every morning as a regular duty of the farm. Figs. 409, 410, 411 show in a general way what is suggested.

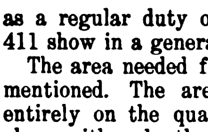

Fig. 412. Manner of laying tile for subsurface sewage disposal. Note the open joint and method of covering.

The area needed for the artificial beds has been mentioned. The area for natural beds depends entirely on the quality of the soil. The hardest clays with only three or four inches of top soil should have an area 100 feet square for every ten persons in the house. If the soil is porous and the discharge takes place once a day, twenty-five feet square for each ten persons would be enough. It is not possible to get too much land ready, and, on the other hand, it is not difficult to add to the area prepared if the sewage remains on the land in pools. The fundamental principle is to bring the sewage in small infrequent quantities in contact with the surface of the soil, letting the bacteria act and so destroy the organic matter. It should not be difficult with this in mind to arrange tanks and land areas to bring about the desired result, viz., the disposal of the fouled water in an effective and wholesome way.

INSTALLATION OF FARM WATER-SUPPLIES — DETAILS OF WELLS, PUMPS AND POWER.

By *W. H. Rayner*

In considering the various methods of securing a suitable water-supply for a farm or country place, the natural resources should first be carefully examined. If there is a spring near the residence or other farm buildings, a measurement of the water it will supply should be made to determine whether it will furnish a sufficient quantity for the necessary requirements. Then a level should be run between the spring and the foundation of the buildings; and should the spring be found to be ten feet, or more, higher than the point of delivery, the problem becomes one of piping the water of the spring to the house and other buildings, depending on gravity to distribute it to the points where it is to be used.

Should the spring be on a lower level than above stated, but not exceeding twenty feet below the point of delivery, and within a reasonable distance, a line of pipe may be run from the spring to the house or other building and the water drawn by the use of a suction pump or, preferably, by using a suction and force pump, the water, after passing the pump, being distributed by a system of piping to the points where it is used. In laying the pipe to draw water a long horizontal distance, there should be an ascent from the spring or well to the point where it is desired to locate the pump. The suction pipe should be laid in the trench by aid of a spirit-level, so that there will be a constant rise from the spring to the pump, in order that the air in the pipe may pass freely out through the pump. A vacuum chamber should then be attached to the suction pipe as near the pump as possible.

Should the spring be more than twenty feet below the foundations of the buildings, it will be necessary to place the pump at the spring and use some mechanical power to force the water to the point of delivery.

Wells.

When a satisfactory spring is not available for water-supply, the next method to be considered is that of sinking a well. The well should be located at a convenient point on high ground, not very near the buildings. The depth that it is necessary to go for water will determine, in a measure, the kind of well to be put down. The depth may be determined, in some cases, by a knowledge of the character of the soil and the experience encountered in making other wells in that locality.

Common dug wells.—The earliest and most general method of making wells is by digging a circular hole in the ground, and then walling it with stone, cement or brick, or curbing it with lumber. Recently, large-diameter sewer pipe has been used to curb dug wells. The tools required in digging a well are a short-handled spade, a pick, a strong bucket, and a rope and windlass. With these tools, three men can usually put down a medium-sized well, including the wall, through earth, at the rate of fifteen feet per day for the first thirty feet. As the depth increases, the work will proceed more slowly, as it requires more time to draw the earth from the well and to lower the material for the wall. When sand or gravel is encountered in digging, it may be necessary to curb the well with lumber, held in place with circular forms made up like the rim of a wheel. This requires some skill, but is readily understood by any mechanic. When solid rock is encountered it is necessary to drill and blast until a seam in the rock is reached that will supply the quantity of water required.

In digging a well, it is advisable to go several feet below the water-vein that will supply the well. This will form a reservoir that will increase the efficiency of the well. In finishing a dug well, three or four feet of the top of the wall should be laid in cement, and the wall extended several inches above the ground level and filled around with earth to secure good drainage away from the well. A dug well should have a tight cover not less than two inches in thickness. If ventilation is required, it should be secured by the use of a ventilating shaft, and not by openings through the platform.

Driven wells.—When the underlying soil contains water in a bed of sand or gravel within twenty-five feet of the surface, a driven well may be made. It is cheaper to install and for many reasons is preferable to a dug well.

To put down a driven well the following material is required: Galvanized pipe (1¼ inches diameter, for ordinary farm use) in 8- to 10-foot lengths, a drive-well-point of the same diameter as the pipe, a gas-pipe cap to protect the threads of the pipe in driving, and a heavy wooden maul. The point is made by perforating a piece of pipe, two or three feet in length, with about fifty 5-16-inch holes to the foot, and covering the entire surface with No. 60 brass strainer cloth held in place by a perforated brass jacket, the lower end of the perforated pipe being provided with an iron point that projects beyond the sides of the pipe to protect the brass screen in driving. In making a driven well, a pit five feet deep and four feet in diameter should be dug first and properly walled. The drive-point should be screwed into one section of pipe to which the cap is securely attached, and driven into the bottom of the pit at a point about six inches from one side, as this will permit the use of pipe-tongs in the pit. While the pipe is being driven, it is advisable to turn it constantly to the right with a pair of pipe-tongs. By revolving the pipe in this way it will drive more freely and will keep in a straight line. When the sand or gravel bed containing water is entered by the point, this fact is easily determined by the freedom in driving or by the sound made by the sand and water against the point as the pipe is being turned. The driving must be continued until the top holes in the screen are well below the water-level.

To clear the well before attaching the regular pump, a pitcher spout pump should be used. This test pump, which is screwed on the drive-well pipe, should be primed and worked on a short, steady stroke until the water comes freely. The pumping should then be continued for an hour or more, or until the water comes clear and free from sand, after which the pump that is intended for permanent use may be attached to the pipe. A new and expensive pump should never be used for clearing a driven well.

Tubular wells.—In many parts of the country, where the water-supply lies far below the surface, too deep for a driven well, it is necessary to make what is known as a tubular well. This differs from a driven well in having a larger pipe, and the pipe is driven with an open shoe on the lower end instead of a closed point, and the earth that comes in contact with the shoe is removed from the inside of the pipe as the driving proceeds, instead of being forced to the sides, as in a driven well. All this is accomplished by a drilling and jetting process, and requires a drilling machine.

Tubular wells are generally made by using two-inch galvanized gas pipe, the pipe being drifted to clear it of roughness on the inside, and the ends being reamed to permit the seating and removal of the pump plungers. A tubular well cylinder provided with a shoe is used below the well pipe. This cylinder is made of extra strong pipe bored smooth on the inside, or brass-lined, and is usually three or four feet in length. The drill that is operated through the inside of the pipe and cylinder consists of a drill-bit with a hollow shank threaded for one-inch iron drill pipe, and provided with a valve over the opening through the shank. The hollow drill rod is provided with blind valves in the couplings, so that, when the water flows into the well pipe and the drill is operated, the cuttings in the form of mud in a thin mixture will be brought up through the hollow drill rod and discharged through an outlet above the surface of the ground. When the pipe has been sunk into the sand or gravel containing water, the drill is withdrawn, and by the use of the drill rod a drive-well-point, with a flush point that will pass through the shoe, is inserted and pushed down into the sand or gravel below the cylinder, a turned coupling being used on the upper end of the point to prevent its being pushed below the shoe. On this turned coupling, the check-valve of the pump is seated by pressing it down with the drill rod. The plunger and pump rod is then inserted and the pump head connected to complete the well.

Drilled wells.—A drilled well is made in every way very similar to a tubular well except that larger pipe or casing is used, and a cylinder is not placed at the bottom of the well pipe, the pump pipe and cylinder of the pump being inserted after the well is completed.

In drilling, a heavy solid drill of proper size for the well-casing is used, and to it is attached a heavy drill rod 20 to 40 feet in length; these are provided with a pair of connecting links, called jars, which permit a recoil and secondary stroke on each primary stroke of the drill. These tools are operated by being attached to a cable that is given an intermittent motion by the action of the drilling-machine. The cuttings are removed by the use of a sand-bucket with a valve in the bottom end. When a drilled well penetrates a water-bearing stratum of rock, the water often rises in the well to a point comparatively near the surface of the ground, so that in placing a pump in a well of that character it is not always necessary to have the pump extend to the bottom of the well. Whenever the source of the water from which the well is supplied is higher than the ground line at the mouth of the well, the water will flow from the well, sometimes with great force; such flowing wells are called artesian wells.

Drilled wells can be made only by the use of proper machinery, but are mentioned here in order that a description of the pumps to be used for the farm water-supply may apply to them, as well as to dug and driven wells.

Storage of water, and piping.

After the well or spring is ready and tested, the attention should be directed to the proper means of storage of the water, so that a supply may always be at hand without the continuous operation of the pump. This is usually secured by erecting an elevated supply-tank on a sub-structure of sufficient height to deliver the water to the various points where it will be used. If the water is intended only for house use and for live-stock, the sub-structure need be only ten feet in height; for hothouse uses the bottom of the tank should be sixteen feet above the level of the ground; for lawn sprinkling and to supply water in the second story of buildings the bottom of the tank should be elevated twenty feet; for fire protection the tank should exceed by twenty feet the height of the buildings it is intended to protect. Figs. 413 to 416.

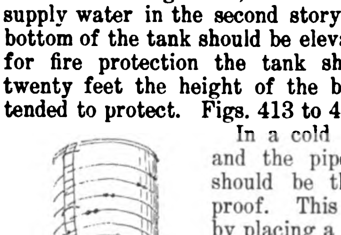

Fig. 413. The storage tank does away with the necessity for the continuous operation of the pump. The height of the tank varies with the purpose for which the water is to be used.

In a cold climate the tank and the pipes leading to it should be thoroughly frost-proof. This is accomplished by placing a flat roof over the top of the tank and surmounting that with a conical roof, the space between the two coverings forming a dead-air space. The joists supporting the bottom of the tank should then be ceiled and boxed in, and the space between the ceiling and the bottom of the tank filled with mineral wool or other frost-proof material. The pipe or pipes leading to the tank should be wound with tarred paper and then covered with inch thickness of hair-felt securely bound with small copper wire. Then the pipe should be inclosed by a box of sufficient size to allow a three-inch air space between the pipe and the box; this should be inclosed in a second box, leaving a four-inch dead-air space between the first and second boxes. In extremely cold climates a third box is required. The boxes must be well made of matched lumber, and the outside box should be lined with tarred building-paper. Many persons prefer to house in the entire tank and sub-structure, using the inclosed space for a tool repair room or dairy, keeping a fire in the building during cold weather. Figs. 415 and 416.

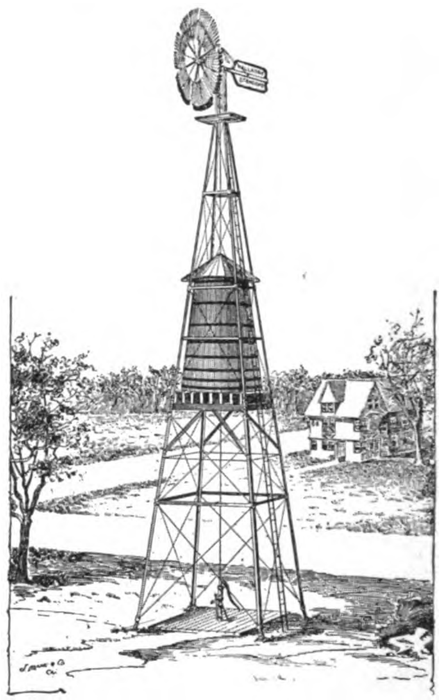

Fig. 414. A common form of windmill storage.

Before deciding on a storage tank, a survey of the surrounding ground should be made to determine whether a nearby hill can be found with sufficient elevation to furnish the water-pressure required. When this is the case, the best possible system can be installed by building a cemented cistern in the hill (Fig. 417), forcing the water through a pipe into the bottom of the cistern, and using the same pipe to return it to the point of distribution. As the system can be made entirely underground and the pipes be placed below the freezing point, this arrangement is entirely frost-proof without the use of artificial means.

Still another form, known as the pneumatic water system, is coming into frequent use, especially when the gravity systems described above are for any reason impracticable. This consists of the use of an air-tight boiler-iron tank imbedded below the surface of the ground, or, better, located in the basement of a building, and connected at the lower part with the conducting pipe from the pump. It is also fitted at the bottom for the discharge pipe of the tank. As the water enters the tank, the air is compressed in the upper part, which produces a pressure that forces the water to the points where it is required for use. This system in its completed form requires the introduction of additional air from time to time. This is accomplished on a shallow-well pump by connecting a small air cock to the suction pipe of the pump; but in the case of deep wells, a small air pump should be installed for this purpose, the same to be operated when required by the same power that operates the well pump; or it may be operated by hand. Forty to fifty pounds pressure to the square inch may be carried on the tank, which should be provided with a pressure gauge; also, a gauge-glass or try-cocks should be used to determine readily the water-level in the pressure tank.

Fig. 415. A housed-in tank. The inclosed space may be used for a tool-room. In cold weather a fire may be kept to prevent freezing.

With any of the systems described, the water may be piped to the sink and to the drinking-troughs or tanks for the stock. The water-supply in the troughs can be controlled by the use of float-valves and floats, which will determine the level of the water in each trough regardless of the elevation of one trough above the level of the other, the float closing the individual valve when the trough is filled sufficiently and allowing the valve to open when part of the water has been used; or, each trough may be provided with an underground cock, with a wrench to open and close it when desired. Fig. 418 shows a cement drinking-trough, that is a great improvement over the old leaky and unsanitary wooden troughs. It should be found more frequently on farms.

Fig. 416. A housed-in windmill, costing about $1,000.

When the water-supply is intended principally for stock, the necessary storage of the water can be secured by increasing the size of the drinking-tanks so that they will carry two or three days' supply. In such cases, a small pressure tank, holding about thirty gallons, should be placed near the kitchen sink in the house, with the conducting pipe from the pump connected to the bottom of the pressure tank, and the discharge pipe from the pressure tank to the stock tanks connected at the top, so that all the water pumped passes through the pressure tank. By tapping the conducting pipe just below the pressure tank and inserting a bib-cock, and placing an inward-opening air vent in the top of the pressure tank, the kitchen is always provided with a supply of the freshest water to the extent of the size of the pressure tank.

In laying pipe for a water-supply, no pipe smaller than one inch inside diameter should be used for stock water, and no size smaller than three-fourths inch should be used for distribution inside the house. A horizontal check-valve should always be used in the underground discharge pipe just as it leaves the pump.

In estimating the quantity of water to be stored, it should be remembered that on an average each horse or cow requires daily about seven gallons, each hog about three gallons, and each sheep about one gallon. An ordinary family uses ten to twenty gallons a day, not including lawn-sprinkling or floral culture (see also page 293). Provision should be made also for increased requirements, and the tanks or elevated cistern should hold at least two days' supply.

Power for raising water.

The usual mechanical powers for pumping and forcing water are hand and force pumps, the hydraulic ram, windmill, gas or gasoline engine, and the electric motor.

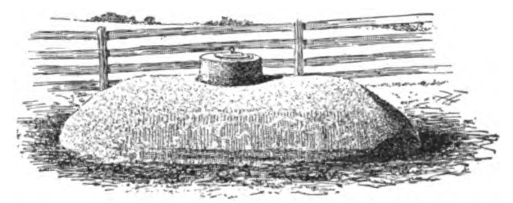

Fig. 417. Top of cemented cistern on a hill, before covering with earth.

Pumps.—In any part of the country where the elevation is not greater than two thousand feet above the sea-level, a suction pump can be used in a well in which the permanent water-level is not over twenty feet below the platform of the well. Whenever a suction pump is used, a strainer foot-valve should be placed on the lower end of the suction pipe.

In driven wells, a suction pump is attached to the well pipe, with the pump cylinder within twenty-five feet of the permanent water-level. In some cases it is necessary to dig the well-pit deeper and extend the length of the pipe and connecting-rod between the cylinder and the pump-stand, so that the cylinder may be within suction distance of the water.

In deep dug and drilled wells over twenty-five feet to the water, only what is known as deep-well pumps should be used. In such pumps, the cylinder is extended into the well by means of the pipe and pumping-rod, and the cylinder should be located below the permanent water-level in the well. When a deep-well pump is set in this way, it is not necessary to prime the pump in starting it; and in case anything lodges under the pump-valves, it is likely to wash out without permanent injury to the pump.

In fitting a pump for a deep well, it is essential that the couplings on the pump-rod always come above the couplings on the pipe, as the rod, being on the inside of the pipe, is always screwed together first, and then the pipe is moved down and screwed together over the rod.

In selecting a pump for a well, the purposes for which the pump is to be used must be determined. If for hand use, to pump into a trough or pail at the well, any ordinary iron lift pump or wooden pump may be used; but in an ideal farm water-supply system, the water should be delivered either to an elevated tank or reservoir, or directly to the stock tanks and house tank where it will be used.

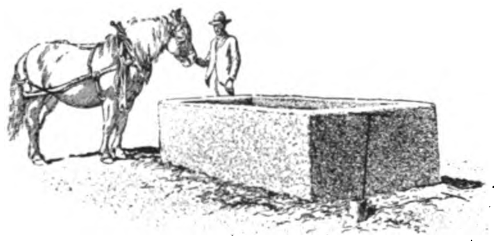

Fig. 418. Cement drinking-trough, a great improvement over the old leaky wooden troughs.

In this case, a good underground windmill force pump should be selected. These force pumps are made with an underground valve, so that by throwing a single lever the pump will force water either from the spout of the pump or through the underground pipe to the supply tank or reservoir. A pump of this kind can be operated by hand, windmill, or other motive power.

The hydraulic ram.—Hydraulic rams are used only with springs (or streams), and, before deciding to use this power, the quantity of water the spring will afford per minute must be measured. This may be done by catching the discharge in pails or barrels for that length of time; if the height of the water delivered is five or less times the feet-head, the discharge must equal about seven times the quantity of water the ram will be required to deliver, or a ram can not be used. It is necessary that there be a fall from the spring to the ram of three or more feet. The ram may be located at a distance of forty to one hundred feet from the spring; the fall in any case must be determined by the height it is required to force the water. A fall of one-seventh the height the water is to be lifted will be very effective. The size of the ram is determined by the quantity of water the spring will supply, and the size of the drive and discharge pipes are in turn determined by the size of the ram used. There are two valves in the hydraulic ram. One, an impetus-valve, is usually placed opposite the drive pipe; the other is in the base of the air-chamber, which opens upward and acts as a check-valve between the air-chamber and the body of the ram. Fig. 407.

The principle on which the hydraulic ram operates is as follows: The water flows from the spring through the drive or supply pipe, which should have an incline of about thirty degrees from the horizontal, and passes out through the impetus-valve of the ram. This valve is so balanced that before the flowing water has entirely reached its maximum speed, the flow will be sufficiently strong to raise and close the impetus-valve. When this occurs, the sudden checking of the flow causes the momentum of the stream to raise the valve in the air-chamber and to force part of the water into the chamber, where, by compressing the air, the power is stored that forces the water through the discharge pipe to the point of delivery. As soon as the flow in the drive pipe has expended its momentum, the impetus-valve drops back and the operation is automatically repeated.

In piping for the hydraulic ram, short turns and elbows in the pipe should be avoided. The ram should be placed in a covered pit where it will be protected from the frost. For estimates of the capacity of rams, see page 296.

Windmill.—Suitable power for operating a pump should be considered. The cheapest and most convenient power for pumping, when conditions permit, is the windmill. Windmills vary in type and efficiency from a four-arm direct-connected paddle-wheel, erected on a single post, to the modern curved blade, back-geared, steel windmill, erected on a scientifically constructed steel tower. The modern windmills are models of efficiency and strength, and are built on lines that are pleasing to the eye, adding effect to the landscape that is not usually attained by so practical an object. Figs. 414 to 416.

To select a proper-sized windmill for the purpose required, the speed of the wind in the particular locality should be considered. In the United States, this information can be readily secured from the nearest weather bureau station. When the average speed is above eight miles per hour, throughout the year, the following table may be followed safely:

						Lift
8-ft.	diameter	windmill,	3 -inch	diameter	pump,	40 ft.
8-ft.	"	"	2½-inch	"	"	70 ft.
10-ft.	"	"	3 -inch	"	"	70 ft.
10-ft.	"	"	2½-inch	"	"	120 ft.
12-ft.	"	"	3 -inch	"	"	100 ft.
12-ft.	"	"	2½-inch	"	"	180 ft.
12-ft.	"	"	2¼-inch	"	"	200 ft.
12-ft.	"	"	2 -inch	"	"	300 ft.

When the average speed of the wind is less than given above, a proportionally larger diameter windmill should be chosen.

In the lift that is required of the pump, the elevation above the ground to the top of the elevated tank or cistern should be added to the depth of the well. Steel windmill towers are now constructed so that they may be erected from the ground up, section by section. This eliminates all risk in erecting, and the method is readily understood by persons not previously familiar with this class of work; and it permits the erection of the tower near buildings, trees and shrubbery, without injury to them.

A modern windmill, carefully selected for the work required and properly installed, is practically self-operating, being so constructed that it will run at a normal speed in winds of varying intensity, allowing the wind-wheel to be forced entirely out of the wind in a severe gale and gradually squaring the wheel up to the wind as the gale dies to a moderate wind, bringing the full face of the wheel to the wind when only a light breeze is blowing. Various automatic devices are in use for the purpose of throwing the windmill out of the wind when the supply tank is full, and allowing it to go into the wind when the water-supply needs replenishing. These consist of pressure cylinders attached to the force pump, so arranged that when a float-valve in the supply tank is closed by the water rising beneath the float, a back pressure is put on the system of piping, with the result that it operates the plunger of the regulating cylinder, which is attached by proper connecting rods and levers to the pull-out wire of the windmill, throwing the wheel out of the wind and preventing the overflow of the supply tank or reservoir. When the water in the supply tank has been reduced by use, the pressure is relieved on the regulating cylinder, and the wind-wheel resumes the normal position to receive the wind. So-called ratchet regulating devices may also be used for this purpose. They consist of a series of teeth, usually on the arc of a circular casting, with proper pawls to engage and disengage in the teeth, operated by a lever attached to the pumping rod of the windmill, the engagement of the pawls being controlled by a float in the supply tank. The casting containing the toothed segment, being connected to the pull-out wire, will throw the wind-wheel out of the wind when the float in the tank is lifted to a designated height, and when the float is again lowered will allow the wheel to return to its normal position. By the use of either of the above-described methods and the self-governing feature of the windmill, all that is required of the user is to see that the windmill is kept oiled and the plant in working condition. Fig. 420. (See also pages 224-226.)

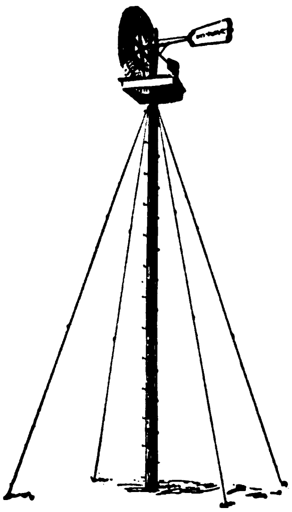

Fig. 419. A simple cheap windmill installation that is very serviceable when carefully constructed.

Gas and gasoline engines.—Gas and gasoline engines are next to be considered for use in supplying power for a farm water system. In making a choice between a gas or a gasoline engine, accessibility of gas should be taken into account. In localities where natural gas is abundant or artificial gas may be had at reasonable rates, a gas engine should be chosen, while a gasoline engine, because of the general distribution of gasoline, may be used economically almost anywhere. Gas and gasoline engines, suitable for power for a farm water-supply, may be had in sizes of one to ten horse-power. When the engine is to be used only for pumping water, a one or two horse-power engine will usually meet all requirements; when the water-supply plant is on a larger scale, a proportionally larger engine and pump may be used. This, however, necessitates the use of larger pipe than is recommended for the requirements of an ordinary farm. The principal requirements in the construction of a gas or gasoline engine of the four-cycle type are a proper cylinder, the piston-head connected to the crankshaft with a connecting rod, a combustion chamber with means for introducing the gas or gasoline in proper quantities for each explosion, a sparking device, and ports so arranged that the first revolution of the engine will exhaust the product of the last explosion and introduce the proper amount of air and gas or gasoline for the next charge; the second revolution will compress this mixture and introduce the spark at the proper point of the revolution. These conditions are secured in various ways by different manufacturers, but the general methods are the same in all makes. The uniform speed of the engine under variations of the load is controlled by a governing device regulating the introduction of the gas or gasoline to the combustion chamber. [For further information, see article on Farm Motors in Chapter VI.]

These general principles are usually easily understood by the user, and their application to any particular engine is readily acquired from printed instructions, usually furnished by manufacturers of such engines. Because of the fact that wells vary greatly in depth, and the height decided on for the supply tank or reservoir will also vary, it is better to purchase an engine independent of the pump rather than a direct-connected or combined outfit. By so doing, the engine can be belted to the pump, securing the proper reduction in speed by a selection of proper-sized pulleys. In this manner, the pump may be operated at a speed that will insure its highest efficiency on the work it is required to perform, and not be overloaded, as is sometimes the case on direct-connected machines. The engine can also be removed readily for use on other work, when so desired. Power pumps with belt pulleys

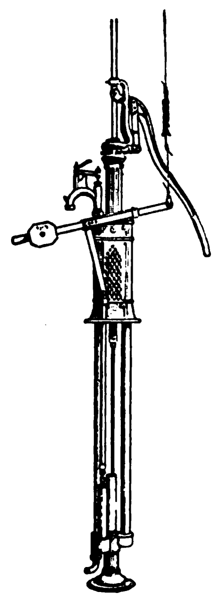

Fig. 420. Regulating device for windmill pump.

can be secured and, except in the case of deep-well pumps, are usually double-acting, giving a uniform belt pull on the engine.

Since the bill removing the tax from denatured alcohol has now become a law, we may expect a rapid development of alcohol-burning engines. Gasoline engines can readily be adapted to alcohol.

It will help one to determine the capacity of a pump to remember that, when working on a 10-inch stroke, at thirty strokes per minute, a pump will deliver an amount in gallons equal to the square of the diameter of the cylinder in inches. For example, a 3-inch diameter pump on a 10-inch stroke at thirty strokes per minute will deliver the square of three, or nine gallons per minute. If the pump has a 5-inch stroke, it will deliver one-half that amount, or four and one-half gallons; or, by a change in speed, the result will be in proportion of the speed to thirty strokes per minute. If the pump is of the plunger type, the speed of the motor should be reduced by the selection of belt pulleys, so that the pump will be operated at a normal speed of thirty to forty-five strokes per minute, according to the work required.

To determine the horse-power required to pump a given number of gallons of water in a given length of time to a given height, it is only necessary to remember that it requires one mechanical horse-power to lift approximately thirty gallons 100 feet in one minute; all other quantities and heights may be estimated in their proportionate relation to this rule. This allows for a reasonable factor of loss by friction and other causes, in both the engine and the pump.

Electricity.—Another source of power that sometimes may be used for operating a pump is electricity. This is a very satisfactory method when electricity may be had at reasonable rates, but at the present time it is not often available for farm use. However, when this method is decided on, a motor should be selected of the requisite horse-power to operate the pump, and of a type to conform to the current to be used.

INSTALLATION OF FARM WATER-SUPPLIES—DETAILS OF PLUMBING

By *Clarence A. Martin*

The problem of plumbing in an ordinary farmhouse is altogether a serious one, not so much because of difficulties in securing a water-supply and disposing of the wastes, as because of trouble from freezing and bursting of water pipes in winter. Whenever plumbing fixtures are installed it is necessary, of course, to have both supply and waste pipes, and it is imperative, unless we wish to invite disaster, to have these pipes, more especially the supply pipes, thoroughly guarded against freezing. In a house heated by a hot-air furnace, steam or hot water, this is a simple problem; but when the heating is from the more primitive stove the situation calls for the exercise of the greatest care and personal judgment. Placing the bathroom directly over the kitchen, with pipes exposed on walls and ceilings of the kitchen, might be a solution in one case; or running pipes well in the interior of the house and wrapping them thoroughly with hair-felt or mineral wool, or placing them near a warm chimney, might offer another solution; while still another way is to place a hot-water circulating pipe from the kitchen-range boiler close to the cold-water supply pipe. This will keep the water from freezing so long as there is a fire in the range; but it will also heat the water standing in the cold-water pipes, which may be a disagreeable feature. This, however, might be overcome by having a stop or "shut-off" in the circulating pipe to cut off the circulation whenever it is desirable to do so. All pipes must be completely emptied when the building is to be left without heat for any length of time in cold weather. This is best accomplished by placing a stop-and-waste in the main supply pipe where it enters the building, and having all the pipes of the system incline so that they will empty at this point when the stop, to cut off the supply from outside, is closed and the waste opened. If all pipes cannot be run to drain to this particular point, then outlets should be placed at all low points that would otherwise form traps to hold water in the piping.

All supply pipes inside of the house, so far as possible, should be kept in plain sight and should not be concealed in walls or between floors and ceilings, where it is difficult to locate leaks or other troubles and still more difficult to correct them. A feature not at all essential, but very desirable, is that there should be stops or "shut-offs" in the supply pipes to the separate fixtures. This makes it possible to shut off the supply to any one fixture for repairs without having to close down the whole system, a state of affairs that would be especially annoying in the country if the repairs were of such a nature as to require the services of a plumber who might have to be brought from a considerable distance.

Each plumbing fixture should have a separate trap in the waste pipe, and in no case should the waste from a fixture have to pass through two traps before reaching the sewer trap outside the house. The traps to the separate fixtures should be so located as to be accessible for cleaning at any time without disturbing other work. When water pipes are emptied to prevent freezing, or if the house is to be left unoccupied for a period of several weeks, the traps should be emptied of water and filled with oil, otherwise the evaporation of the water would break the seal of the traps and admit sewer gas into the rooms; or, in cold weather, the water might freeze and burst the traps.

In the country where long lines of piping may be required, or where the work of making repairs or changes must often be done by the "handy man" about the place, it is well to make frequent use of union couplings in order that pipes may be easily taken apart, although union couplings, because of the packing required, are more likely to leak than regular couplings. It is advisable, also, to have a miscellaneous supply of extra fittings and a few tools. Two pipe wrenches, a good combination pipe vise, pipe cutter and dies should be provided. A soldering iron is desirable when there is lead piping, and it is indispensable for repairing household utensils.

The kitchen sink is one of the things no longer looked on as a luxury. The cast-iron porcelain enameled sink, with back of the same material and with roll rim, is cleanest and best for moderate-cost work, and is most appreciated by the neat housewife. For all practical purposes it is quite as good as the solid porcelain sink and is much less expensive. Even a very cheap sink of heavy sheet-metal with colored enamel is better than a plain cast-iron sink and will cost little if any more. A kitchen sink should not be smaller than 20 by 30 inches, while 22 by 36 inches would be large for a small kitchen. The height of the sink from the floor may be almost anything the housekeeper wishes; 30 inches is rather low, 32 inches is a popular height, while 34 inches is preferred by many. The statement so often made that sinks should not be placed on outside walls because of freezing is mostly nonsense. If the pipes are kept out in the open kitchen instead of being placed in the walls, and are not run up in front of a window so as to be exposed to direct drafts, there is something radically wrong either with the construction or with the heating of the kitchen when pipes freeze. The sink should be fitted with ample drain-boards, preferably one at each end. The space under drain-boards and sink should be left open so that it may be kept clean and sweet at all times.

An ordinary bathroom usually contains three fixtures, namely, a bathtub, a lavatory and a water-closet. There has been a great advance within the past few years in all that pertains to the art of plumbing, and in no branch of the work is this more apparent than in the fixtures themselves. The old tin-plated copper tub set in a wooden box is no longer tolerated even in the very cheapest of work, but in its place we can put a neat cast-iron porcelain enameled tub at practically the same cost. This tub, like the kitchen sink, should have a roll rim, and should be set without any woodwork whatever either on top or around it. The standard width of the modern bathtub is 30 inches, and the length may vary from 4 to 6 feet.

The lavatory may be a porcelain or earthenware bowl with a marble slab and back, or it, too, may be of cast-iron, enameled with white porcelain and with no joints or separate parts making crevices to catch dirt and breed bad odors. The iron enameled lavatory is smaller, more compact, and in very many respects better than the marble lavatory, and it should cost less, but, unfortunately, it really does cost a bit more.

The water-closet that is now used almost universally is of solid white earthenware and of the syphon-acting type. Enameled cast-iron closets have been in use in cheaper form for factories and institutions for a long time, but it is only within a few years that these have been so improved as to indicate that they may in time supersede the earthenware closet for some of the better work of moderate cost. There are two kinds of syphon-acting closets in common use,—the syphon hopper and syphon jet. Of these two, the syphon jet is clearly the better; but it is also the more expensive, and for ordinary work a good syphon hopper closet serves very satisfactorily.

If the bathroom cannot be included in the scheme of plumbing, then a water-closet of the long-hopper type might be installed in an outer room near the kitchen or the wash-room. This closet is so arranged that the water flows only while the closet is in use. At other times the water is cut off and the pipes emptied automatically to a point several feet below the floor level, where they may be protected from freezing. This type of closet cannot be recommended from a highly sanitary point of view, but it is enough better than the old privy vault or the earth closet to call for consideration under some circumstances.

The difference in the cost of plumbing fixtures, if we start with those here recommended, is very largely a matter of minor detail, such as enamel paint and gold stripes on the outside of the bath, fancy marble and elaborate nickel legs or brackets for the lavatory, mahogany or quartered oak seat and tank for the water-closet, and so on, all of which may be well worth the cost if one has the money to pay for it.

INSTALLATION OF FARM WATER-SUPPLIES—SPECIFIC EXAMPLES

It now remains to work out the foregoing suggestions and adapt them to particular cases. Examples of the way in which farm water-supplies are sometimes worked out are given below, being adapted from Bulletin No. 29, Cornell Reading-Course for Farmers. The needs of barn supplies are discussed also in the articles by Burnett and Cook, and of residence supplies in the article by Wing, in Chapter VII. It pays to have all work set by an expert.

Roof water systems for residence.

(1) In the attic is a tank which is supplied from the rain water from the roof. In addition, the house has a large cistern in the basement from which an extra supply may be pumped in case the rain-water is insufficient to fill the tank in the attic. In the bathroom is a hand pump connecting the cistern in the basement or cellar with the tank in the attic. The attic tank is 9 feet long, 3 feet wide and 4 feet deep. The framework is made of 2 x 4 hemlock (planed). It is lead-lined. The tank is in the attic of one of the wings of the house. It receives the roof water from the main building of the house, but not from the wings. The area of this main building, however, is only about one-quarter of the entire roof system. The cistern beneath the house is large, having a capacity of 110 barrels. This receives the roof water from the wings and also the excess of roof water, if there should be any, from the overflow from the tank in the attic. It often happens that in certain times of the year

the rainfall is insufficient to supply the tank in the attic. In order to meet this deficiency, a good hand pump has been put in the bathroom, by means of which water is pumped from the cistern below up to the tank in the attic. In the dry summer months, considerable water has to be pumped up. The water is heated in a common cylindrical heater which stands back of the kitchen stove and is connected with it. There has been no difficulty in having warm water. The sewage is emptied into a cesspool 12 or 15 rods from the house. The cesspool is a comparatively large one, being fully 10 feet deep and about 6 feet in diameter, and is lined with stone. The system works to perfection, no repairs having been necessary and no trouble experienced since it was installed.

(2) A tank is in the second story of the house, made of 2 x 4's laid up and spiked together. This is lined with sheet lead. The lead is much better than copper, because it will stretch somewhat if the walls of the tank spring. The copper is likely to split or seam, resulting in leakage. On the other hand, the lead lining is not safe when the water is to be used for drinking purposes. Water from the roof is caught in troughs and stored in this tank (see O, Fig. 421), which is about 5 feet deep and 5 feet square, inside measurement. The water from the parts of the roof too low to run into the tank is conducted into a cistern in the cellar of the house (B B, Fig. 421). A pump in the kitchen is so arranged that it may be used to pump water from the cistern below or from the well in front of the house into the tank above. The owner has seldom needed to use the pump for this purpose, but the pump is in constant use to pump the drinking-water from the well to the kitchen. The tank on the second floor supplies water to a hot-water tank attached to the kitchen stove, to a sink in the

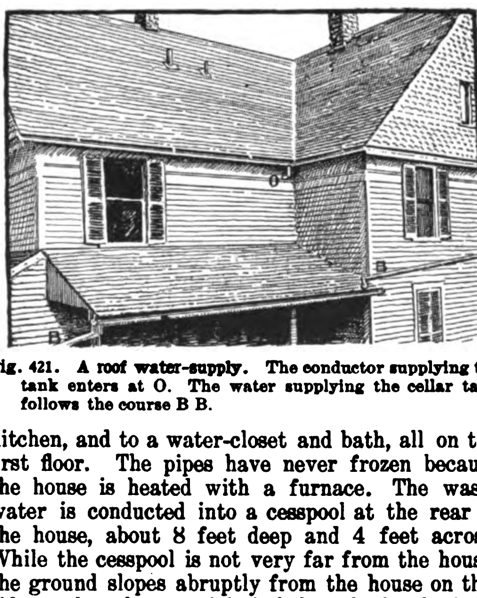

Fig. 421. A roof water-supply. The conductor supplying the tank enters at O. The water supplying the cellar tank follows the course B B.

kitchen, and to a water-closet and bath, all on the first floor. The pipes have never frozen because the house is heated with a furnace. The waste water is conducted into a cesspool at the rear of the house, about 8 feet deep and 4 feet across. While the cesspool is not very far from the house, the ground slopes abruptly from the house on this side so that the top of it is below the level of the cellar bottom. It is covered so that no odors escape. It is on the opposite side of the house from the well and enough lower than the well to prevent contamination of the drinking-water.

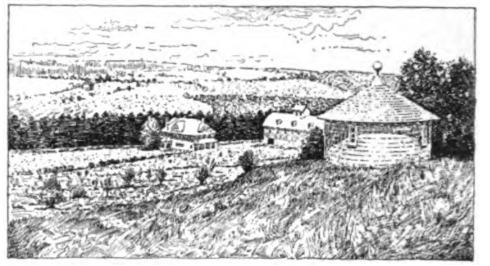

Fig. 422. Circular storage tank receiving water from springs. It supplies the residence, horse and cow barns, milk-room, boiler-house, and a small cottage. Three fire hydrants are also connected.

Gravity systems, from springs, for residence and barns.

(1) Four springs supply a large reservoir (Fig. 422) and one spring supplies a small reservoir. One-inch lead pipes bring the water from the springs to the reservoirs, and a two-inch galvanized pipe brings the water from these reservoirs to the various buildings. These systems are connected and arranged so that water can be used from both or either of the reservoirs in all the buildings. There are three fire hydrants and about two hundred feet of hose, and an average pressure of about fifty pounds. One will be surprised at the quantity of water used. This system now uses water from five good springs. Should more be required, a well will probably be drilled near one of these reservoirs and a windmill erected. A drilled well near by with a pressure tank in the ground, and some practical power to keep it filled, would save considerable money in digging and laying pipe lines and building reservoirs, and would probably give excellent satisfaction.

This system supplies water to the house, which contains four bathrooms and modern equipments; to the cow barn, accommodating over a hundred head of cattle; to the milk-room and boiler-house, using large quantities of water in certified milk work; to the horse barn and a small cottage near by.

(2) The farm is in a hill country in which there are abundant springs of good water on the hillsides. Springs on one of the hillsides are run into a thousand-barrel tank, and from this reservoir water is carried to the buildings through a four-inch cast-iron pipe with a head of about 200 feet. This supplies two bathrooms and water-closets in the residence, and also bathrooms and plumbing complete in three tenement houses that accommodate the farm help. When the system is once installed it works automatically and to perfection and becomes an indispenable part of the farm equipment. Five springs are run into the reservoir on the hill, these springs being ten to twenty rods distant. The reservoir is built in the ground, of stone, 20 feet square and about 10 feet deep. It stands nearly full of water the year round. The water as

it leaves the springs has a temperature of about 42° Fahr. In warm weather it sometimes reaches as high as 50° in the reservoir and in the buildings as high as 55° to 57°. The reservoir is 100 rods from the residence. Pressure at the house is about ninety-five pounds per square inch. The supply pipe from the reservoir is laid five feet deep. The reservoir supplies the residence, creamery, stables, boiler-room and the three cottages. The cost of the entire plant has been about $1,000.

An air-pressure system for residence.

A galvanized steel tank of 200 gallons capacity is in the cellar of the house. This is air-tight and has a discharge pipe from its lowest point. A special pump is provided to pump the water from the well into the tank. By turning an air-cock provided for that purpose the same pump may be used to force air into the tank. First, air is pumped in until the gauge registers about ten pounds pressure. This amount of pressure is sufficient if the water does not have to be forced higher than 22 feet. The water may be carried as high as necessary merely by increasing the air-pressure. Then water is pumped into the tank until the pressure gauge registers twenty-five pounds. It requires ten to fifteen minutes' pumping each morning to provide enough water for the family (six persons). On washdays it is necessary to pump to a higher pressure or to pump more than once. If the plumbing is good and care is exercised to prevent escape of air, it is not necessary to pump air into the tank very often. This system has proved very satisfactory. The water is kept in good condition by the action of the air on it; being in the cellar it keeps cool in summer and is not in danger of freezing in winter. It is much easier to support a tank in the cellar than in the top of the house, and there is not so much danger of trouble from its springing a leak. The apparatus is patented. A hot-water tank attached to the kitchen stove provides hot water for laundry-tubs in the basement, sink in the kitchen, and the bathroom on the second story. In the bathroom there is a wash-bowl, closet and bathtub. The installation of the system cost about $200, including all plumbing.

CHAPTER IX

RURAL ART

INTEREST IN OUTDOOR ART has two phases,—the expression of the countryside as a whole, and the character of individual properties. Every person is interested in his community as well as in his farm: what the community is in both physical and social features is therefore of great concern to him.

It is everybody's concern how the neighborhood looks. One slovenly place is a blot on the neighborhood. The scenery is one of the assets of a country; and the appraisal of this asset is bound to increase with time, because the educated mind is always sensitive to its surroundings. Any person who needlessly or ignorantly despoils the scenery is guilty of an offense to the community, whether so recognized in law or not. The highways are the property of the public: therefore no person has a moral right to use them for the display of advertising signs without the consent of all persons that use the highways; and if persons tacitly consent, it is evidence that they are not sensitive to the beauties and meaning of the wayside. The offense is heightened when the advertising signs are both ugly and untrue; and it should become wholly unbearable when the signs are vulgar and vicious. Signs advertising private business have no right on fences, rocks, trees and roadside buildings. They are a public nuisance. The law may not yet recognize them definitely as nuisances, for our legal measure of a nuisance lies chiefly in the fact that the object or practice interferes with public health. Neither may a man recover damages of one who puts an offensive sign opposite his door, although he may recover if another injures his business in ever so small degree. All this means that the law may not keep pace with advanced public

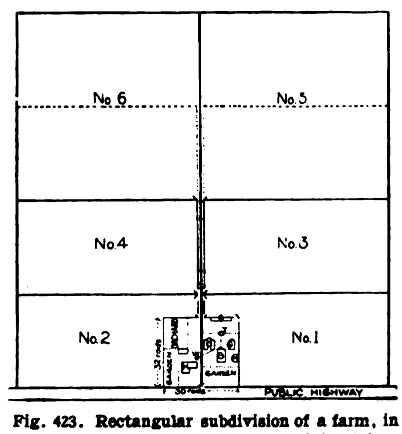

Fig. 423. Rectangular subdivision of a farm, in the flat and homogeneous country of the plains.

sentiment; and it is admission that in the question of damages we yet stand mostly on the basis of money. The time will come when a person may not offend his neighbor's eye with any more impunity than he now offends his purse. As soon as any community rises to the point of desiring offensive objects removed, the law will be made to cover the cases; and this is already being done in some places with offensive advertising signs.

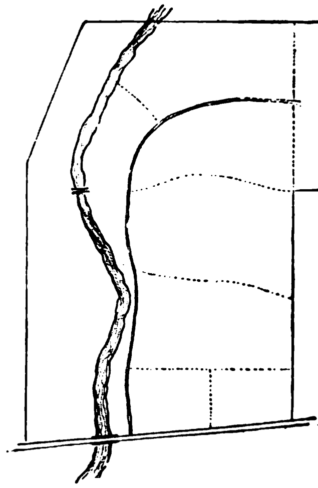

Fig. 424. An irregular division of a farm, following contours.

Rural art has a much wider scope, however, than merely to remove unsightly and offensive objects. It is constructive. It will make the rural scenery artistic in composition, and keep it so. There is now a widespread discussion of the art of city building, considering not only how the city may be fundamentally effective, convenient, well-constructed and sanitary, but also how it may be attractive and even beautiful in its entirety as well as in some of its parts. There is also need of discussing the art of country making, an art that is yet unwritten and even unnamed. The first consideration in the country, as in the city, is to make it effective for the kinds of affairs that are to be conducted there: this also will be the first step toward making it artistic, for in fields as well as in buildings the beautiful must first be fit. The expression of the countryside may be heightened by the preservation of certain great natural features, the proper subdivision of the farms, the character of buildings and the arrangement of them, the layout of roadways, the planting or utilizing of the roadsides, the kinds of fences, the proper planting of bushes and trees in home and other grounds, the absence of objectionable objects, the good keeping of private and public property. Advantage must be taken of every interesting natural condition or object. This is so easily said that it is likely to make no impression; but it is difficult to execute, because it depends on personal appreciation of these conditions and surroundings. This appreciation is now growing rapidly. We shall have societies to further these various objects.

We have already discussed the interest of the public in such private property as buildings and fences. We have also suggested (page 144) that the public is concerned even in the layout of the farm. There is such a thing as an inartistic subdivision of a farm. In a flat country, the subdivisions may or may not best be on strict rectangular lines; but in a hilly country it is manifestly both inconvenient and ungraceful to follow such lines. It is strange how deeply the feeling for right lines is seated in the general mind. Note that we still lay out towns in straight lines even on steep hillsides. It is said that a rectangular and symmetrical layout of a farm is most practical and convenient (Fig. 423): it may be or it may not be. In general, the layout should conform to the contour. If a farm is divided by a stream or bluff, it may be best for the lanes to follow these natural boundaries, even though the boundaries are not straight. (Fig. 424.) This may mean better grades, more directness, less expense in maintenance. A natural-soil or sod roadway may be better on such contours

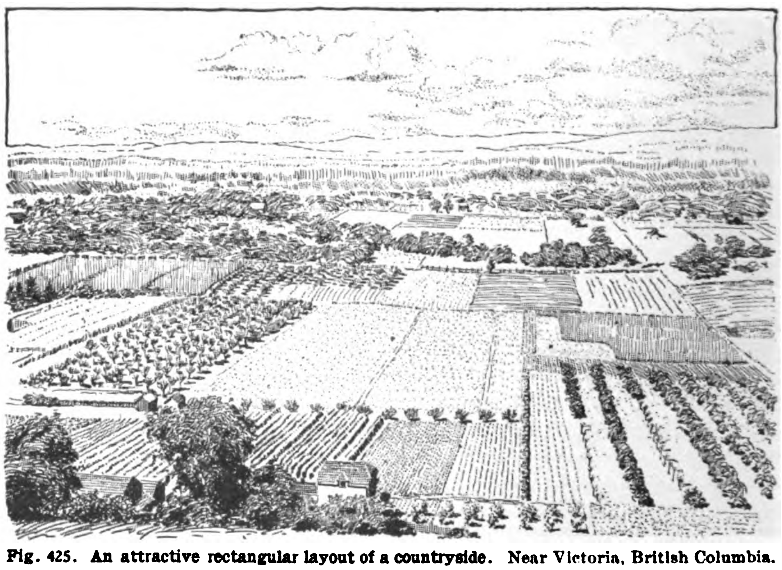

Fig. 425. An attractive rectangular layout of a countryside. Near Victoria, British Columbia.

than a gravel roadway in other places. The tilled fields may be on one side of the roadway or lane, and the woods, natural pastures or waste-land on the other side. Such an arrangement would usually make for the good looks of the place as a whole. There is a beauty of rectangular lines and another beauty of flowing lines.

Fig. 426. A farm in the hill country, laid out on the contour lines.

The discussion of landscape gardening is usually confined to definite areas or properties, as yards, parks, school-grounds. It has scarcely touched the larger phases. The best American writing on this larger aspect is "Charles Eliot, Landscape Architect," a book of more than 700 pages, being a memorial by President Eliot, of Harvard, to his lamented son. There are a number of books devoted to the layout and adornment of premises, as Downing's two books, Landscape Gardening and Rural Essays; Kemp, Landscape Gardening; Van Rensselaer, Art Out of Doors; Waugh, Landscape Gardening; Parsons, How to Plan Home Grounds; Maynard, Landscape Gardening as Applied to Home Decoration; Long, Ornamental Gardening for Americans; Scott, Suburban Home Grounds; Bailey, Garden-Making.

TASTEFUL FARM YARDS

The primary consideration in the construction of a building is to make it serve its purpose as directly as possible; and the second step is to consider the general mass-effect rather than the details. The same order should be observed in the layout of the grounds. Many persons, to judge by the results, conceive of a yard only as a place to set out plants: they must have roses or hydrangeas, particularly if the nursery agent displays the glories of these subjects. This is like thinking of a house as a construction for the display of fancy chimneys and glowing paint. What kind of trees and bushes to plant represents the final stage, not the first, in the making of a good yard.

The yard affords a setting for the buildings; it connects the buildings; it provides access to the highway, the well, the barn; it provides space for various kinds of service. Everything about the yard should be convenient: the grades should be "easy," particularly in the direction in which there is much travel; the surface should be smooth enough to allow of easy mowing; the walks should connect the different parts in the most direct and pleasant way; the drive, if any, should be such that it is easy to drive over and to keep clean; there should be no objects or plantings that require the expenditure of much time in tending. Everything about the yard should be "in keeping" or in good taste: if a farm yard, it should be simple and unpretentious; it should be large and generous; it should have a good turf; in some part of it there should be shade and an attractive place in which to sit or lie in warm weather; it should look "natural," —that is, nature-like, free, country-like, devoid of primp and oddity, harmonious. It should express a home-like feeling.

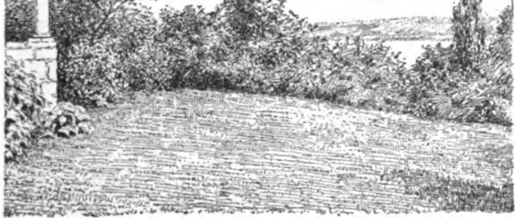

Fig. 427. A tasteful farm yard, with an open-centered lawn and naturally planted border. Openings in the border permit glimpses of the lake and hills beyond.

These remarks do not mean that strictly formal and geometrical gardens are always to be avoided. On the contrary, there are many cases in which such treatment is much to be desired, but these cases seldom occur in farm premises and therefore they are not considered here.

This discussion brings up the saddest part of farm life,—the fact that so many of the places are not home-like. Here lies the very root of most of the discontent with the farm in the minds of the young. One can not blame a youth for desiring not to remain in an unattractive place; we should rather think him lacking in gumption and imagination if he desired to remain in such a place. One can drive over almost any farm road and find places in which nobody would care to live. It would be unnecessary to inquire at the house why the boys and girls are leaving the farm. Most of these places are either bare or untidy, usually both. One may well wonder how it is possible for some persons to keep their places so bare of attractive vegetation. It would seem as if they must spend more effort in preventing trees and bushes from growing, than would be required to plant and

Fig. 428. Planting massed at the sides and an open center. The walk is direct. The general effect is good. The house is of the city type.

tend a grove or a shrubbery. Abandoned houses soon come to be attractive because of the trees and bushes that grow about them unmolested and unscared.

The picture in the landscape.

There are some farm premises of which one feels that he would like a picture to hang on his walls. There are others of which he would not possess a picture even if it were offered in a gilt frame. It is worth while to recall the places that one knows, and see in which category they fall.

After one has classified the places in this way, he should try to determine why he has done so. Almost before one knows it, he will hit upon the essentials of a good place. It is excellent practice to analyze the impressions and to jot down the results.

Probably the first result of the analysis will be a feeling that one likes the place as a whole, for the general impression that the entire scene makes, rather than because particular trees or other objects please. In other words, the scene is a picture, not merely a collection of objects. If the home

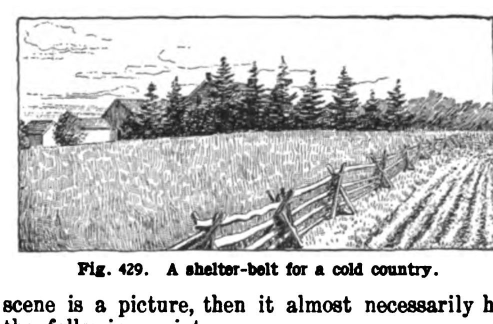

Fig. 429. A shelter-belt for a cold country.

scene is a picture, then it almost necessarily has the following points:

The place is well-clothed, or furnished, with trees and shrubbery;

The residence is prominent and has a good setting;

There is an open space of sward, if it is in a grass-growing country;

The trees and smaller plants are mostly massed or grouped at the sides or in the rear, rather than scattered all over the place;

There are no unnecessary fences, walks or drives;

There are no mere curiosities conspicuously placed in the yard, as piles of stones, odd rocks, shells, pieces of statuary;

The place is neat and picked up, looking as if it has good care and as if the residents love it.

In Fig. 427 is shown a lawn that combines many of these suggestions. The house, built of native stone, has a good outlook. The open-centered lawn is bordered by natural planting. Openings in the border permit of glimpses of the lake and hills beyond. The contrasts of Figs. 428 and 430 are suggestive.

Some specific suggestions.

The commonest fault with farm yards is that they seem to have no thought or care bestowed on them. If care is given them, however, the effort is likely to be expended in scattering plants here and there or in making "beds" in the sward; and this is usually worse than nothing at all, because it

Fig. 430. Scattered and aimless planting. A bank of shrubbery against the side of the porch, and an open greensward, would have been much more tasteful.

emphasizes the value that is placed on individual and trifling objects rather than on the place as a whole. Such yards are usually given over to the care of the women. Many persons buy furniture in the same spirit—a certain chair merely because it is handsome as a chair, without considering whether it is in keeping with the house or with the other furniture. Many houses might well pass for furniture stores; many yards might well pass as nurseries.

It is a good rule to set out no plant until one is sure that it is needed as a part of the general effect that one is trying to produce. Merely because a plant is "pretty" is no reason for planting it. There should be some scheme, and all the planting should fall in with the scheme. What this scheme shall be cannot be answered off-hand, for every place is a problem by itself; yet a few general rules or suggestions can be given:

(1) Lay out or plan the place. Plan the walks and drives and fences (if any must be had) so that they will best serve the purpose for which they are needed. It is always a help to make a map of the

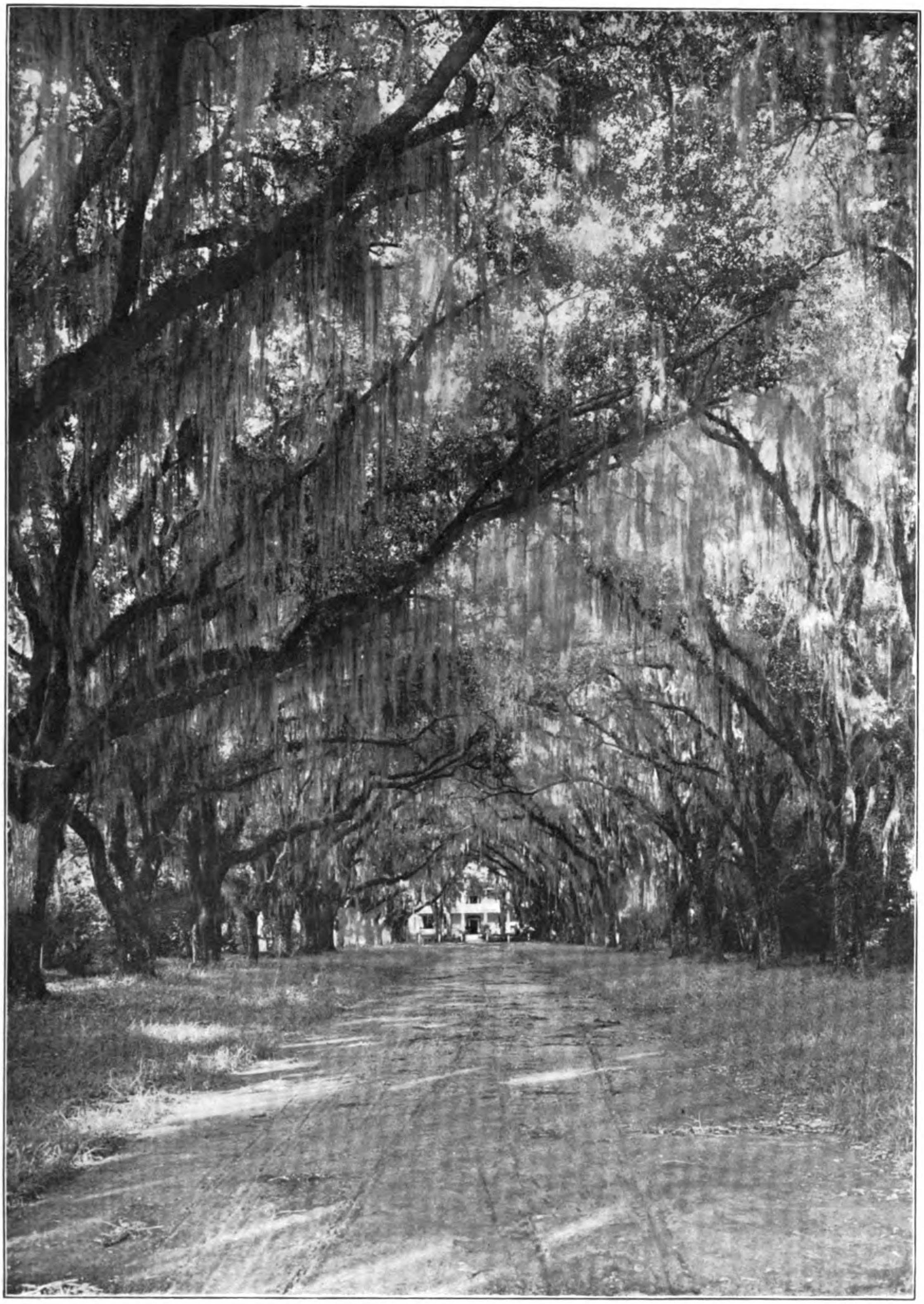

Plate XVII. An old-time southern home, with avenue of live-oaks. Rosedown Plantation, St. Francisville, Louisiana

area, drawn to a scale, locating on it all existing permanent objects, as trees and buildings.

(2) Plan for an open center, in front of the house. Wherever sod grows well, this space should be sward or lawn. If the area is small, it can be mown with a lawn mower; if large, the greater part of it, at some distance away from the house, can be mown three or four times a summer with a field mower.

(3) Plant part of the sides of the place (Fig. 428). The rear, in particular, should be planted. Note how home-like and cosy a farmhouse looks if there is an orchard behind it, and how bare and bleak if it stands out alone against the sky. These plantings may be trees or bushes, or both. Fig. 372 shows a very tasteful setting for a farmhouse.

In many places, a windbreak or shelter-belt may be desirable (Fig. 429), particularly in a treeless country or one from which the forests have been largely removed.

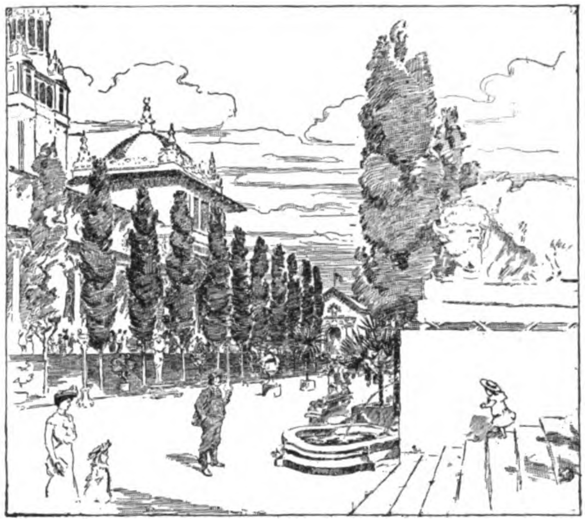

Fig. 431. Slender trees planted for their "architectural" effect.

(4) Set at least a part of the plants in groups. Note how attractive an old fence-row is. One may not want a fence-row, but hints can be got from it. Do not plant the things in severe rows. Plant them irregularly, do not shear them year after year, and then let them grow into each other freely and naturally. If one wants a few special and showy plants, as hydrangeas, plant them near a group of other plants, not drop them promiscuously over the front yard, where they bear no relation to anything else and have no particular meaning. One ought to feel sorry for the isolated bushes and dejected little trees and sad geranium beds that are set down here and there without any use or reason, and which are forced to make a constant struggle with the grass.

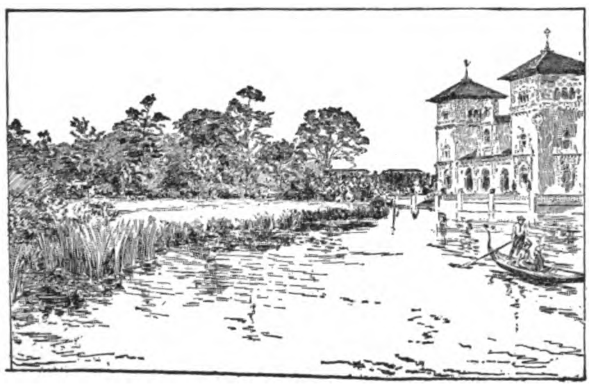

Fig. 432. A landscape inclosed by a building and by planting.

(5) Be careful not to overcrowd the residence with trees, especially with evergreens. It is always advisable to provide shade, but it is easy to make the place gloomy and depressing. It is seldom that a residence looks well in a grove,— the grove is likely to swallow up and domineer the buildings, and the place lacks in openness and free sweep (see Fig. 373).

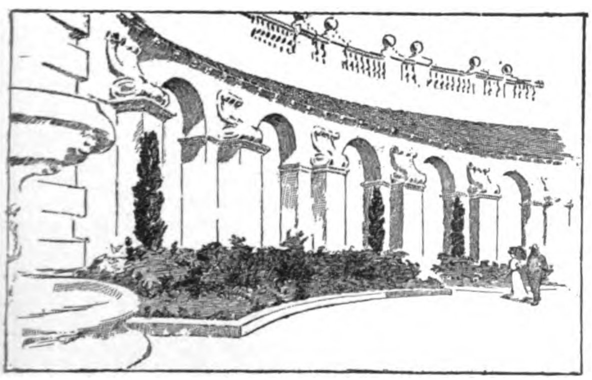

Fig. 433. Low planting in a formal border in front of an arcade.

(6) Plant as freely of bushes as of trees, perhaps even more freely. It is a common mistake to give too little attention to the shrubs. They comprise the minor furniture of the place, filling it in about the margins, relieving it of bareness and bleakness.

(7) The main plantings of the trees and shrubs and herbs should be made of the kinds that one knows and that are sure to grow. Many of the native trees and shrubs are very desirable and are reliable. The horticultural novelties may then be used to touch up the place; if they are used to excess, the area looks exotic. On both buildings and yards it is easy to place too much mere ornament.

The planting has a powerful effect in setting off the buildings, if properly done, as well as in furnishing the place itself. The reader will recall how much attention is given to the planting about buildings in parks and exposition grounds. Figs. 431 to 435, being sketches in the grounds of the Pan-American Exposition, Buffalo, will illustrate this, although, of course, these views are not directly applicable to farm places.

(8) Flower-gardens and vegetable-gardens should be at one side or in the rear. They should be a secondary or incidental part of the place, rather than the main note or feature. Flower-gardens are for the growing of crops of flowers, and they should be in good soil and in a place where they can receive good care; they cannot have good care in little isolated beds in the lawn, and moreover, they have no relation to anything else in that position. Bulbs appear to better advantage when seen as an edging to a group of shrubbery or as a border, than when standing in a mound in the middle of the yard. Many flowering plants can be grown in the borders, about the foundations of the house, sometimes along or near a walk, but these are for the purpose of heightening the effect of the place as a whole and they are subordinate; flowers grown for flowers need tillage, manure, training, the same as good garden vegetables do. One would not think of growing beets and cabbages in pinched holes in the sod; yet we try to grow geraniums and pansies in such places.

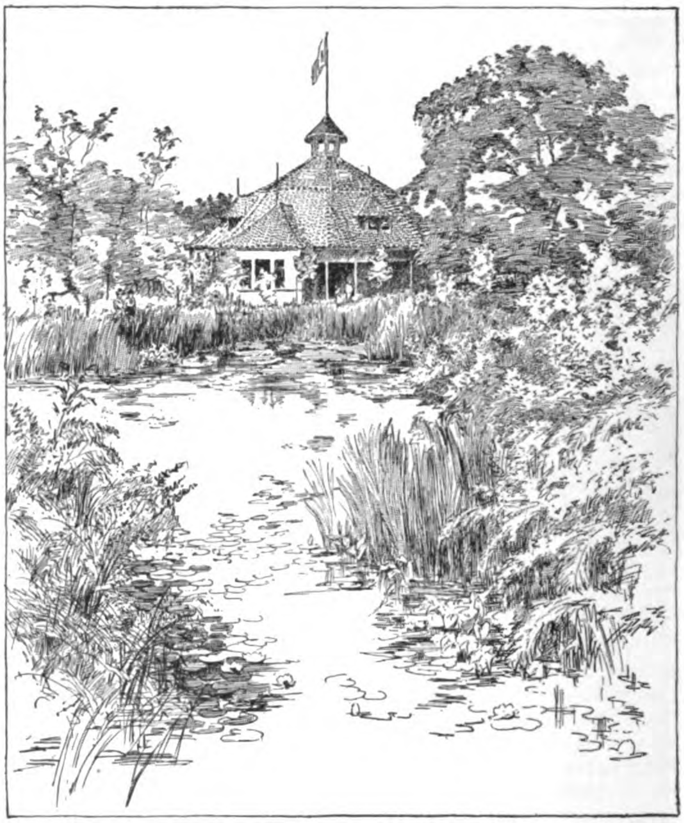

Fig. 434. A building well-set in planting. (Fisheries Building, Pan-American Exposition.)

The flower-garden should produce the best crop of flowers, just as a vegetable-garden should produce the best crop of vegetables. A selection can be made of the common flowers that will give abundance of bloom throughout the season. If one has strength and time for it, it may be well to have a formally laid out flower-garden, with regular walks and edgings. (Fig. 437.) This will consume much labor for the amount of crop that is produced, but it may yield another kind of satisfaction that is well worth the while; for it is not all of gardencraft merely to grow good flowers.

If there are children in the family, an area should be set aside for their use in the making of gardens. It is astonishing how little the farm boy in general knows about the propagating and growing of plants; yet this should come as a kind of natural knowledge, developed as the child grows. It is astonishing, also, how little affectionate regard he may have for plants; yet this should be acquired on a farm, for it is naturally a part of farm life.

(9) It is advisable in most cases to make low plantings against the foundations of the house, in order to relieve the hard lines and to tie the building to the greensward. This can easily be so managed as to prevent darkening of the cellar windows and to obviate any danger of rotting out the woodwork. A free-growing bush may be a good reinforcement at the corner of the house, if it is allowed to take largely its natural course, by not being kept sheared. If the eaves drip, it will be impossible to grow anything very satisfactorily near the house; both for the good of the planting and of the foundations, eave-troughs should be provided. A few vines may add much to the look of snugness and coziness of a house, particularly on porches; and brick or stone houses may well be covered or draped with some climber adapted to the region.

(10) If there are walks and drives, they should be as few as possible and still serve the place, and all curves should be direct. (Fig. 438.) Walks and drives usually do not add to the good appearance of a property; therefore they should be subordinated. The novice usually lays out too many of them and makes them too conspicuous. They are expensive to build and to maintain, particularly if they are on slopes

where they will wash. In general, try to avoid cutting the yard in two by walks and drives: let them come in from the sides, as far as possible, rather than from the front. Very often it will be desirable to follow the bend of a creek on a hilly farm to get an easy grade. This will in a measure determine the directness. All drives and walks should be thoroughly well drained underneath, by filling a liberal excavation with stones or cinders. All "runs" should be conducted away in large permanent culverts or capacious permanent catch-basins. Surface washing must be avoided.

In laying out walks and drives, avoid all unusual and striking curves, all wiggles and mere crooks. Curves are usually better than straight lines, unless the yard is small, but the curves should appear to be necessary and useful in order to fit the place. Fig. 440 shows inadmissible forms.

(11) The treatment of the place should conform to the region. In the North, green sward is the key-note. Far South and in arid regions it may not be.

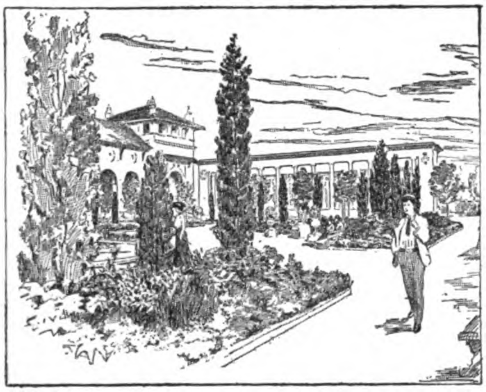

Fig. 435. An effect produced by the style of planting.

In the South it is the custom to leave the premises open on the ground line, planting heavily of shade trees but sparsely of bushes, in order to allow freer sweep of winds. It is a question whether it is good art to make a verdant lawn the basis of the landscape garden in a warm arid region where sod and greenery are not a part of the natural landscape. The Spanish-American treatment of grounds, or some modification of it, which is fundamentally different from the English and East-American treatment, may possibly be best for the southwestern regions.

(12) The yard should have good care. The first necessity in the maintenance of any place is common neatness,—the same kind of pride in tidiness that the good housekeeper has in her work. The slackness in the keeping of yards can rarely be charged to the lack of time, as is so commonly said; it is rather a lack of utilizing the spare minutes as a thrifty business man or professional man economizes his time. It is often said that the busiest man has the most time. He organizes his efforts, does things quickly, then takes up something else.

The yards show on their face what kind of effort

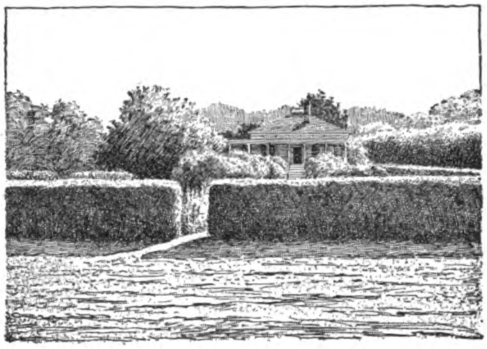

Fig. 436. A California treatment of a farm yard. Inclosed by a hedge of Monterey cypress; the interior freely planted, with practically no sward.

the man puts forth to keep his place in order; and good housekeeping and good care-taking are as important as good architecture or good landscape gardening. It is probable that half the farm yards are devoid of home-like and attractive features; and very many of them are an offense to a sensitive eye. The pride in a good yard is as necessary to a fully successful farm business as pride in serviceable and attractive clothing or in a good turn-out. These things all go together, being an expression of the resourcefulness of the man.

The general plan of the place should make for cleanliness and tidiness. If the premises are convenient and direct, and devoid of fussy features, the labor of keeping them in presentable condition will be much reduced. These remarks apply with particular force to barnyards. One would almost think that many barnyards are arranged for the special purpose of catching water. If buildings and yards are well planned, there will be little mud in the yard. Roof water must be carried away, the slopes properly made, the manure and barn drainage taken care of. There is little excuse for a miry barnyard.

The love of plants.

The furnishing of the garden is accomplished mostly by means of plants; therefore, if one is not

Fig. 437. A semi-formal flower-garden. It is interesting, if one has time to devote to it. It formerly contained more beds with narrow earth walks between, but, as years advanced, the woman who made it found the task of keeping weeds in check to be too great, and therefore she turned the walks into lawn. Most persons will prefer simpler flower-gardens, with more flowers.

interested in plants he cannot have a living interest in a garden. It is to be feared that most persons are interested in plants only when they bloom. The real satisfaction to be got from plants, however, comes from an interest in them merely as plants and not alone as color or perfume. The plant is interesting when it first pushes through the ground; when it shoots upward into its accomplished form; when it blooms; when it sets fruit; when the framework stands stark in the winter. This love of plants is greatly intensified when one grows them himself. The commonest plants may be as interesting as the rarest; and some of the woods and field plants when transplanted to the yard may be the choicest of all for certain purposes. Figs. 441–445 show interesting common plant forms.

It is manifestly impossible to give lists of plants in this writing, for the article applies to no special region. The gardening books give lists; so do many of the nursery and seed catalogues; gardeners and other plant-lovers may be consulted for the particular locality.

The winter landscape.

A good part of the year in northern regions is leafless. We are likely to want to close our eyes to the out-of-doors when winter comes. Yet, if one is to be content in his time and place, he must be in sympathy with the landscape the year round. It is essential, therefore, that we learn to know the trees and the fields and the woods in winter.

The winter aspect of trees is most interesting. The framework is all revealed and the trees seem to be nearer to us than in summer, and they will soon come to mean more. Trees differ remarkably

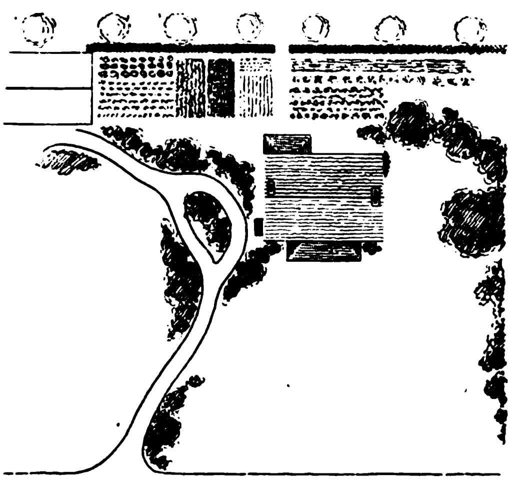

Fig. 438. A suggested driveway and planting for a small yard. The drive is direct, but with enough curve to relieve stiffness.

in expression when the tops are bare. How they differ is suggested by the drawings (Figs. 446, 447, 448). Note the silhouette against the sky of a maple as compared with an oak; of an elm as compared with a maple; of a soft maple as compared with a hard maple. Follow out the curves and crooks of the branches; the method of branching and forking; the kinds of bark; the differences in the terminal spray; the colors in trunk and twig.

One will soon begin to observe the trees closely, and this will be the beginning of interest in them.

Fig. 439. A border. In this case, the border is made of trees and shrubs. Flowers may be planted against it along the front edge.

The well-trained man fills his moments of leisure with observation and reflection of one kind or another; as he rides to town there is something to challenge his attention. It is well to plant the home grounds with some reference to winter effects,—not merely the planting of evergreens for protection, but the clumping together of red-twigged or yellow-twigged or green-twigged bushes. Even the weed stalks standing above the snow may interest one.

We are likely to think of the winter landscape as only black and white, yet it shows a great variety and depth of color. One could not paint it with black and white paint; he would need to mix in much red and other colors. By February the color in twigs and buds may begin to change: this, aside from the lengthening days, is the first indication of spring. Even the surface of the earth itself is not uninteresting in winter,—the brown sward, the subdued marshes, the cover of snow and ice.

Making the lawn and planting.

The first thing to be done in the actual making of a good yard is to grade the surface to the desired contour. Then the permanent location of the groups and single plants should be marked out. If the yard is to be attractive, it must have a heavy and dense cover of sward, if the place is in a region in which grass is a natural feature. If grass itself does not thrive in the region, perhaps some other plant may be used for sward; in Southern California *Lippia repens* is often used. While it may be thought that grass

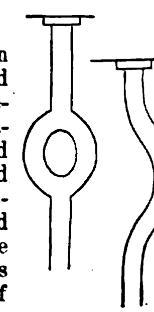

Fig. 440. Forms of walks that are inadmissible. The curves are too striking and are needless for most conditions.

will grow almost anywhere, nevertheless it is difficult to secure a first-class lawn. A lawn is composed of very many fine spears of grass, and a few straggling clumps, however good, may be only a detriment to the lawn if the general run is not in good condition. It is as necessary to prepare the land thoroughly for a lawn as for a crop of wheat or potatoes. This is ordinarily done by deep plowing and then by thorough tillage until the surface of the land comes into a condition of fine tilth. Before the grass seed is sown, all irregularities should be filled and the earth firmly tamped or settled. The lawn is to remain indefinitely and cannot be graded again; therefore every care must be taken to shape the contour properly. There should be slopes leading away from all foundations, if possible. The mature trees should be allowed to stand above the level of the sod, showing their brace roots, as they do when growing naturally. If there are any sour or wet spots in the area, they should be drained with permanent tile or stone underdrains. The land should also be rich. It is advisable to plow under a good coat of manure and, if the land is not in good heart, a heavy dressing of commercial fertilizer will help.

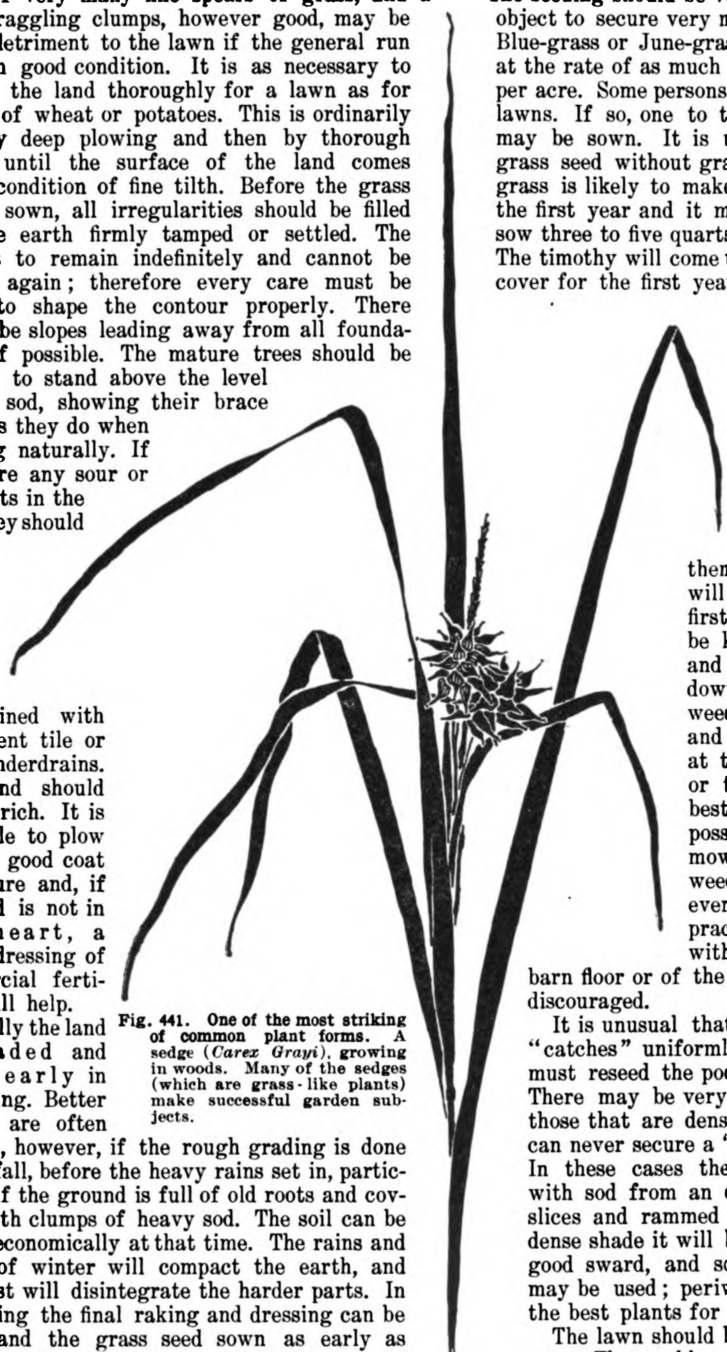

Fig. 441. One of the most striking of common plant forms. A sedge (*Carex Grayi*), growing in woods. Many of the sedges (which are grass-like plants) make successful garden subjects.

Usually the land is graded and shaped early in the spring. Better results are often secured, however, if the rough grading is done in the fall, before the heavy rains set in, particularly if the ground is full of old roots and covered with clumps of heavy sod. The soil can be moved economically at that time. The rains and snows of winter will compact the earth, and the frost will disintegrate the harder parts. In the spring the final raking and dressing can be given and the grass seed sown as early as possible. The earlier the seed is in the ground the better the root-hold it will secure before the dry weather of summer. Many persons like to sow grass seed on a very late snow. It will then be carried into the soil by the melting of the snow. It will need to be raked in, however, if the land cannot be worked soon enough in the spring to allow of such early sowing.

The seeding should be very heavy, since it is the object to secure very many fine stalks of grass. Blue-grass or June-grass is ordinarily used, and at the rate of as much as three or four bushels per acre. Some persons like white clover in their lawns. If so, one to three quarts to the acre may be sown. It is usually best to sow the grass seed without grain. However, the June-grass is likely to make a rather poor showing the first year and it may be well, therefore, to sow three to five quarts of timothy to the acre. The timothy will come up quickly, make a green cover for the first year, and will be gradually crowded out by the June-grass. In most cases the weeds will be very abundant the first year, particularly if stable manure was worked into the soil. These weeds should not be pulled, for the pulling will destroy the young grass. Most of them will be annuals and will die out at the end of the first season. The area should be kept mown all summer, and this will keep the weeds down. If strong perennial weeds, as docks, come up here and there, they can be pulled at the end of the first year or the second year. It is best to mow the lawn, if possible, with a good lawn mower, since that keeps the weeds down and tends to even up the growth. The practice of seeding lawns with the sweepings of the barn floor or of the haymow is always to be discouraged.

It is unusual that a lawn of any extent "catches" uniformly the first season. One must reseed the poor spots year after year. There may be very hard and dry places, or those that are densely shaded, on which one can never secure a "catch" by mere seeding. In these cases the area may be covered with sod from an old pasture, cut in thin slices and rammed firmly into the soil. In dense shade it will be impossible to secure a good sward, and some other ground cover may be used; periwinkle (Vinca) is one of the best plants for shade.

The lawn should be fertilized from year to year. Thoroughly rotted stable manure may be worked into it in the fall or early in the spring. The common practice of piling raw manure on the lawn is to be discouraged. Some good concentrated fertilizer may also be very effective.

The common practice of sprinkling lawns has little to commend it. If the lawn needs water, it should be wet thoroughly. This deep wetting encourages deep rooting and enables the plant to withstand the dry weather, whereas a continued light sprinkling of the lawn probably tends to develop a shallow root system.

Fig. 442. The comeliness and beauty of a plant form. The day-lily, usually grown only for its flowers.

In the southern states, the northern lawn grasses do not thrive except in elevated regions or in small yards that can receive extra care as to watering and fertilizing. The Bermuda grass, however, makes an excellent lawn in the South, although it does not form the kind of sod that June-grass does. Bermuda grass is sown with short pieces of roots, so thickly that the rootlets lie only a few inches apart. The roots may be run through a cutting box, or chopped by hand. The planting is performed in fall or very early in spring. Otherwise the treatment outlined above will apply.

The borders of the groups may be marked out on the ground when the grading is done, by the end of a hoe handle. The shrubs should be planted thickly, perhaps not more than 2 feet apart. They will soon grow together, and if the shrubbery becomes too thick, some of the specimens may be removed. Until the shrubs begin to cover the land, the earth between them should be hoed and perhaps spaded now and then to keep it in good tilth; and a liberal application of fertilizer of some kind is to be advised. When the shrubs and trees are first planted they should be well headed back; but after they are thoroughly established very little pruning will be necessary except to correct a too rampant growth or to check an awkward tendency. In farm yards the practice of shearing bushes should be discouraged. The effect is always best when the place has a free and natural look.

Fig. 443. Clump of the common native blue violet (*Viola palmata*) grown in the garden.

ANOTHER VIEW OF THE ADORNMENT OF FARM PREMISES

By *Charles A. Keffer*

The adornment of the farm should have in view two important factors: (1) saving to the inhabitants whatever beauty the general landscape may afford, and (2) the creation of beauty within the farm domain. The purpose of all efforts at adornment is an improved appearance, the making of the farm home more attractive, primarily for the dwellers therein, and secondarily for the passing traveler. Incidentally, a farm well-arranged and beautified is increased in value, it is an exponent of the esthetic taste of the owner and becomes an educational force in the community.

Fig. 444. An attractive low plant form. The native wild ginger of the North (*Asarum Canadense*).

The great majority of American farms have been laid out without plan, in a haphazard way; and when thought has been given to planning, the controlling principles have been production, the saving of labor, convenience and the economy of first cost. As a result, too many farms are devoid of beauty. The barn or feeding lots face the dwelling, or occupy sites from which the drainage seeps toward the house; no shade, no flowers — everything is sacrificed to crops and live-stock. Indeed, throughout rural America utility is so strongly the dominant idea that there is little appreciation of the beautiful, and almost contempt for esthetics. With the passing of pioneer conditions and increasing prosperity, a growing tendency toward the amelioration of rural life is manifest not only in labor-saving machinery and better buildings, but in the home and its surroundings.

The house area.

The pleasure of the household is the main object sought in farm adornment; hence, the immediate surroundings of the home should be given first consideration. When the farm buildings have been advantageously placed, the work may be confined to the making of a lawn and the screening of undesirable objects in the landscape by judiciously planted groups of shrubs and trees. If the lawn can be merged into a permanent pasture, the partition fence being inconspicuous and largely hidden by a border planting, a spacious, park-like effect will be gained. Economy of maintenance is a leading principle of farm landscape work, since money and labor expended in adornment produce little cash income; hence, the farm lawn should be planned for meadow treatment, rather than the shearing practiced in city gardens. In planting, the trees and shrubs should be massed near the borders, leaving large open areas of grass, so that the field mower can be used to advantage. Mere spottiness (Fig. 430), or any suggestion of orchard-like regularity, is to be avoided in lawn planting, particularly in the country, where the farmstead is so much a part of the general landscape. The greatest beauty in any lawn is the broad stretches of grass, with only enough trees to provide a measure of protection from the summer sun and the play of light and shade on the green sward. When the farm is located in a forest region, the best effect of planting is gained by so placing the tree groups that they will seem to be supported by the native woodland and form a part of it.

Fig. 445. An attractive plant form. Foam flower (*Tiarella cordifolia*), one of the native spring flowers.

Fig. 446. Trees in winter: trace out branching. The first tree is slippery elm — note the horizontal position of lower branches, with upturned tips; American elms in the middle distance; a spruce in the center.

The lawn not only forms a good setting for the house, but it should be the summer resting-place of the family. It should partake of the privacy of a sitting-room while affording the freedom of the open. Hence it should be protected from scrutiny from the highway. When the farm buildings have been set remote from the public road this is easily accomplished, but when the house faces the highway a careful grouping of trees and shrubbery must be planned, so that from the lawn side the border planting may have something of the effect of a natural woodland border, with irregular projections and bays, and an uneven sky-line, the highest plants being set in the broadest masses. Such a planting permits glimpses of house and lawn from without, and by a little care in placing the lower forms where distant objects may be seen over them, admits the best views the region affords.

When the house stands very close to the highway a good effect is secured by devoting the dooryard entirely to flowers, making the lawn at the sides and rear of the house. Much labor will be saved if perennials are used for such a garden, rather than annuals and bedding plants. Columbine, iris, monkshood, bleeding heart, peony, sunflower, black-eyed susan, larkspur, pinks, hollyhock, hardy chrysanthemums, and many other perennial forms are available, a late fashion having resulted in the great improvement of plants of this class.

It is seldom advisable to scatter flower-beds in the lawn. When space and labor are available the flowers thrive better and give a better appearance when grown by themselves in a garden. When placed in the lawn they should be set in beds of simple design near walks or drives, or placed in connection with the shrubbery border. During much of the year the beds are empty, and when placed in the midst of the lawn they break the continuity of the grass cover.

Fig. 447. Swamp white oak, with its characteristic branch form.

The old-fashioned garden, with its flower-bordered walks and its plats devoted to vegetables, is a pleasing feature when well maintained, but economy is served by planting the vegetable-garden so that it can be cultivated with horse-hoes. The flower-garden should have a place near the vegetable-garden, so that labor may be saved in many operations common to both, such as manuring and plowing.

The farm.

The immediate surroundings of the house having been considered, the pastures, fields, roads and fences of the farm should be carefully studied to determine what can be done to improve their appearance without detracting from their convenience and use. In a large part of America the farms are irregular in outline, giving to the fields the same character. Whenever possible, the fields should be so shaped as to hide the division fences from the home grounds. Fences are never beautiful, and they are usually unsightly weed gardens in the country; they obtrude ugly lines on the view, marring the beauty of the landscape. By a little care they can in many cases be done away with entirely, or so placed as to be invisible from the house. When necessarily in view, they should be made as inconspicuous as possible. Some form of woven wire fence best answers this purpose. Roads also are in themselves seldom beautiful, and entail expense in maintenance, so that care should be exercised to reduce them to the lowest practical limit and to keep them out of sight as much as possible.

One of the beauties of all rural scenery is the growing crops, changing from field to field as the rotation progresses (Fig. 425); and few elements of landscape offer more of quiet beauty than the pastures with their herds and flocks. That scheme of farm arrangement that admits of pleasing views of field and pasture from the home grounds adds greatly to the charm of rural life without increase of cost, and may well be considered an important element of farm adornment.

Perfect care is an essential element in good farming, as apparent in the appearance of the property as anywhere in farm management. Well-kept roads, fences free of weeds and in good repair, pastures free from weeds, buildings kept up and painted — these are quite as important items of farm adornment as are lawns and flower-gardens.

Site and environment.

When a farm is to be newly established, great care should be taken in choosing the site of house and barns, in order to take advantage of every good element in the landscape, and to create beautiful surroundings if they do not already exist. In almost all cases a degree of beauty can be had without sacrifice of that convenience which should always be the basic principle of farm arrangement.

If the surrounding country is beautiful, a high location for the home will permit views that will increase its attractiveness (Fig. 427); but if the surroundings are not good, or if there are undesirable features in the landscape that can not be hidden by plantings within the farm, it is better to seek a lower site, having always in mind the necessity of perfect drainage away from the house on all sides.

Fig. 448. A picturesque subject. A time-worn apple tree, such as one frequently finds in old fields and abandoned orchards.

In treeless regions the dominant characteristic of the landscape is extent —great stretches of rolling prairie, grain and corn and grass, with sometimes a row of trees marking the borders of a tiny stream, and small planted groves protecting the better class of farmhouses. Here the farmer must overcome the barrenness of nature by planting trees freely. Instead of straight belts of forest plantation on three sides of his home, with a row of trees bordering the highway, completely cutting off the splendid stretches of field and prairie, as is the common practice, a better method would place the forest belts more remote from the house, and by the use of a greater variety of trees allow occasional breaks in the sky-line, and a few glimpses of the great prairie world beyond the protected area. By including five to ten acres within his windbreak of forest trees, the western planter may provide ample room for feeding lots, a garden and a lawn, compact enough to meet every requirement of convenience, but allowing the separation of feeding lots and garden from lawn by a careful grouping of well-selected trees and shrubs, in which pines and spruces should have a considerable place, though native species, including the wild fruits, should form the major part of the plantings. A few trees in the lawn itself will provide shelter from the sun, but the prairie home will not be in the highest degree successful unless it permits vistas of the open country.

Within the forested area only the high hills and mountains command the extensive landscapes that are common to the plains, and here the effort must be to attain extent of view, rather than to restrict it. The consideration of particular objects of beauty — fine trees, forest streams, open glades and meadows — is of first importance; and often the appreciation of existing esthetic values in the locality leaves little to be done by the beautifier. The natural adornment of mountain farms may be one of their greatest assets.

In the blue-grass regions of Kentucky and Tennessee a peculiar beauty of many farms is the wood pasture, between the highway and the house, in which great forest trees stand at wide irregular intervals, sufficiently distant from one another to allow a rich ground-cover of grass, where herds of fine cattle and horses graze. These park pastures can hardly be surpassed as a means of farm adornment, and they are quite as well adapted to the great majority of the states east of the Missouri river as to the locality named. They afford, in the pasturage, a source of income equal to any other grazing land, and the only care they require is an annual mowing after the blue-grass has seeded.

General purpose.

Landscape gardening as applied on the average farm implies the placing of farm buildings so that they may compose a beautiful scene, with whatever natural accessories may be available, and within the limitations of convenience, utility and low cost of maintenance. The center of interest, and the principal viewpoint of the picture, is the home. The possible extent of the canvas is everything within the range of vision, from every part of the farm; so that, while it is of first importance that the immediate surroundings of the farmhouse should be pleasing, every good object in the neighborhood of the farm should be seen to advantage from some point within the domain, and, as far as possible, all unpleasant views should be screened.

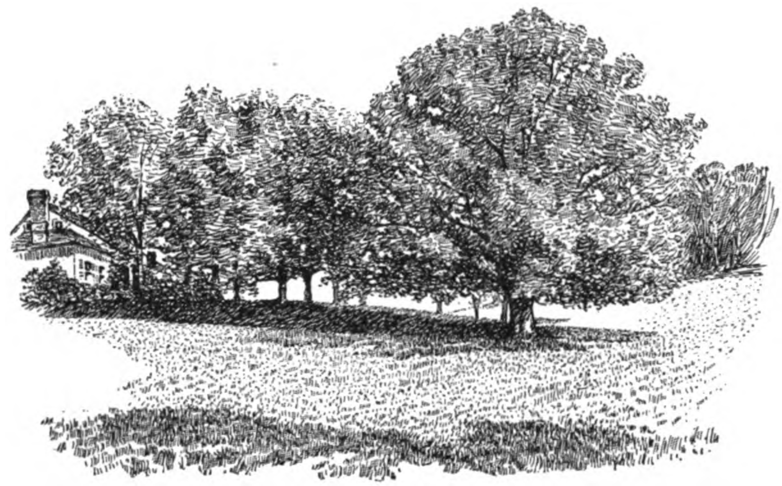

Fig. 449. A Tennessee farmstead. The great oaks and the slope of the land are natural adornments which make elaborate additional work unnecessary.

The most available materials for farm adornment are grass, trees, shrubs and flowers. These should be so disposed as to demand the least possible amount of labor for their proper care, for no return comes from the land devoted exclusively to ornament. The cheapest arrangement, and in most cases the most satisfactory, provides a lawn bordered with trees and shrubs in masses, with comparatively few single specimens and groups within the lawn itself, and with flowers grown in a garden convenient to the lawn, but not within it. From the lawn, as from the living-rooms of the house, whatever is best in the surrounding landscape may be seen through depressions or openings in the border planting, which conceals all unsightly objects, including outbuildings and feeding lots. A site at some distance from the highway not only insures privacy and freedom from the dust of travel, but permits a larger treatment than is possible when the highway passes close to the house.

Within the forest area an especial effort should be made to develop impressions of extent, by enhancing the beauty of distant objects. In the plains, an effect of protection and coziness is more important and is secured by belts of timber, in the shelter of which are the home grounds.

PART III

THE SOIL ENVIRONMENT

All efforts of the agriculturist are conditioned on the producing power of the soil. It is marvelous that the soil may remain fertile even when cropped for centuries. This simple fact is yet without complete explanation. The problem of determining just how the soil supports the life of the globe is constantly becoming more complex, as it is attacked from many sides. The problem makes a strong appeal to persons who devote themselves to the search of truth.

In view of all these facts, it is not strange that there has developed a body of special knowledge concerned with the soil; books are now written on "the soil," and teachers devote themselves to "soils" as a department or chair in a college. One result of this special view is that we are in danger of regarding soil study as an isolated department of knowledge, or the pursuit of this study as an end in itself. The truth is, however, that the study of the soil is only a means to an end: the end is the plant or crop. The soil is one part of the environment or condition of plants. It is a place in which certain activities occur. In earlier days, before specialization had gone so far, the soil was discussed, in the treatises, as one factor or part in a system or treatment. It might have comprised a chapter in a book.

This modern view of the soil has gained popular currency in part because of the new attention that is just now being given to tillage, which comes as a reaction from a generation of domination by soil chemistry and by prepared fertilizers. The chemical study of the soil is as important as ever and great attention is now given to it, but other ways of studying the soil have been added; that is to say, chemistry affords only one means of understanding the problems associated with productiveness of the land. The generation just passed was known for its insistance on increasing the productiveness of soil by the adding of substances. Great importance was attached to guano, peat, swamp-muck, marl, lime, plaster.

Although the tilling of the soil is the most universal occupation of the farmer, it is no longer possible to discuss the soil intelligently from the point of view of mere practice alone. The questions involved are too difficult to be determined by farm-practice methods. They must be treated by soil specialists. This makes the subject appear to be technical and bookish to the unschooled man; but there is no other way of treating it adequately. We no longer ask whether we shall plow deep or shallow, but how we may best accomplish a desired result. Farm practice with reference to soils must be reorganized on the basis of underlying reasons; when this reformation has been effected, we may again discuss the subject satisfactorily from the farm-practice point of view.

The present recognition of the importance of studying the physical qualities of the soil is due largely to the long-continued investigations of Wollny and his contemporaries in Germany. It would perhaps be impossible to find the origin of this type of studies, nor is it the purpose of this editorial to make the attempt. All the soil chemists have given some attention to the physical properties. In this country, Hilgard and others have made notable contributions. S. L. Dana's "Muck Manual for Farmers," first published in Lowell, Mass., in 1842, devotes a chapter to the "physical properties of the soil," and declares that these properties "are the foundation of the great diversity which soil exhibits." Dana also insists on the value of humus, or geine (from the Greek word for the Earth), as it was then called. "In whatever view we regard geine, it is the basis on which rests the whole art of agriculture." In writing for the edition of 1855, he remarks: "Should another edition be called for, I trust it will then and there be shown, in a new chapter on the analysis of the mineral part of soil, that agriculture, in demanding of chemistry any real practical result from such analyses of soils beyond this, their great uniformity of composition, is asking an impossibility. That is my opinion. Not so with the vegetable part of the soil. I have endeavored in the following pages to set forth the high importance of determining the state and condition of this; to show that its presence in soil is of the utmost consequence, and that, without it, full crops are not to be raised. This is my conviction." This conviction accounts for the title of the book,—for muck is composted or seasoned manure rather than an organic deposit in a swamp: the title has probably caused this interesting early book to be overlooked.

But the cotemporary discussion of the soil seems to have little historical connection with these early efforts. In this country, the present vogue of popular soil discussion in reference to physical properties and moisture and tillage seems to have arisen largely with King's book on "The Soil: its Nature, Relations, and Fundamental Principles of Management," published in New York in 1895. Other important works in English are Robert Warington's "Lectures on Some of the Physical Properties of Soils," Oxford, 1900; and A. D. Hall's "The Soil: an Introduction to the Scientific Study of the Growth of Crops," London, 1903; chapters in King's "Physics of Agriculture." Hilgard's book, just from the press, adds another important text. Two other important works, approaching the subject from the geological side, are Horace E. Stockbridge's "Rocks and Soils: their Origin, Composition and Characteristics," New York, 1888, second edition, 1895; George P. Merrill's "Treatise on Rocks, Rock-Weathering and Soils," New York, 1897. Storer's "Agriculture" (1887), although not devoted to the single topic of soils, should be noted as one of the important recent American books contributing to this general field. The establishing of the "Bureau of Soils" in the United States Department of Agriculture, and the development of the subject in colleges by T. F. Hunt and others, have given soil studies a great and increasing experimental and pedagogical value. The experimental and investigational phase has expressed itself chiefly in the development of "soil physics," "soil bacteriology," and the making of "soil surveys"; but the greatest progress is to be expected in actual experimental work, by a combination of all methods, on soil by means of plants, under conditions of control. As a teaching subject, a wholly new line of laboratory work has developed within five or six years, with new apparatus and new field problems. The laboratory work in this country has already developed one manual, Stevenson and Schaub's "Soil Physics Laboratory Guide," New York, 1905. All these departures have passed beyond the schools and have given a new direction to agricultural thought, invention and practice, as the following chapters will show.

Fig. 450.
Dr. Martin Ewald Wollny.
1846-1901.

The latest challenge to our point of view on the fertility of the soil comes from physical-chemical studies; that is, from the study of the physical conditions that favor chemical changes and the physical phenomena that attend these changes, as well as the study of the chemical facts and results themselves. At present, there is active discussion of the "sanitary environment" of plants and of the chemistry of the "soil-solution" following the investigations of the Bureau of Soils. Some of the positions in this new teaching may be stated. The soil contains particles of mineral matter separated from rock. This mineral matter is soluble to a slight extent,—but to a sufficient degree to maintain a soil-solution that is capable of supplying the needs of plants. As rapidly as the plant withdraws the minerals from this solution, further solution takes place of the mineral matter in the soil particles, so that the concentration is maintained. In the common run of cases, therefore, the application of fertilizers has no value in the adding of mere plant-food. The soil soon becomes unsanitary to one kind of plant, probably because the plant excretes substances that are poisonous to itself. The plant tries to escape these poisons by pushing its feeding roots into new soil and covering its old roots with bark. Rotation is conceived to be useful because the excreta of one plant may not be poisonous to another plant. The old "excretory theory" of De Candolle and Liebig, so long discredited, is revived. Any substance that will destroy these poisons will allow the same crop to grow again: the office of humus is largely to cleanse the soil rather than directly to add plant-food; and herein is found, also, the suggested explanation of the good or poor effects that follow the use of fertilizers. Fertilizers that do not add plant-food may give results as good as those that do add plant-food. If these conceptions are sustained, it means a complete change in our attitude toward the subject of productivity of land and an overthrow of our present practices. Some of these ideas are expanded in Mr. Cameron's discussion of the soil-solution on page 369 and Mr. Gardner's account of the wire-basket method of determining the manurial requirements (not the plant-food requirements) of soil in Chapter XIV; and they explain Mr. Bonsteel's remark on page 409 that few known soils are so simple mineralogically or so difficult of solution that they may not supply sufficient food to nourish plants. (Figs. 453, 457, 463–4, 468, 687–8 are adapted from publications of the Department.)

It is evident that we are entering a new epoch in the study of soil fertility. One plant undoubtedly does something to the soil that unfits the soil for certain plants, rather than merely to abstract water and plant-food from it, a subject that will be referred to again in the discussion of rotations in Vol. II. In the present volume, it is intended to present a general view of the attributes of soils and of the principles that underlie the agricultural management of them. Advice as to the fertilizer and soil treatment of the different crops may be expected in the second volume.

Fig. 451. Section of granite, magnified. The crystals are orthoclase, microcline, plagioclase, quartz, black mica or biotite, white mica or muscovite. (Merrill.)

The degree of specialization in soil studies is coming to be so great that a special set of words and phrases, or words with new significations, has come into existence. For the benefit of those who do not have a good lexicon at hand, some of the technical chemical and mineralogical words and ideas that are freely used in these chapters are defined or explained in the Index.

Chemical discussions rest on the conception that there are certain simple substances that cannot be decomposed or separated into other substances, although they may change their form. The simple substances, containing only one kind of matter, are *elements*. New elements are still being discovered. About eighty are now recognized. At ordinary temperatures and pressures, some of these elements are in the gaseous state, others liquid, others solid. For convenience, the elements are represented in technical writings by the initial of the common or other name; as, oxygen, O; carbon, C; hydrogen, H; nitrogen, N; phosphorus, P; potassium, K (Latin, *kalium*); sulfur, S; silicon, Si; calcium, Ca; sodium, Na (Spanish, *natron*); iron, Fe (Latin, *ferrum*); magnesium, Mg; manganese, Mn; aluminum, Al; copper, Cu (Latin, *cuprum*); chlorine, Cl. The elements that are known to be indispensable to plants are less than a dozen.

Only a few of the elements occur in a free or uncombined state. The most marked examples are the gases, oxygen, hydrogen and nitrogen, and the liquid, mercury. Usually two or more elements are combined, forming a *compound*. It is conceived that the combination is on the basis of atomic weights. Water, H_2O, has molecules composed of two atoms of hydrogen and one atom of oxygen. Nitrous acid, HNO_2, has one each of hydrogen and nitrogen and two of oxygen. When another atom of oxygen is added, it becomes HNO_3, nitric acid. When elements combine to form compounds, they lose their identity. Thus iron rust, Fe_2O_3, is very different from iron. But, when the compounds are broken up into their constituent parts, the elements resume their original form. There is neither gain nor loss.

Most elements or their simpler compounds are either *acid* or *alkaline*. In common language, an acid is a substance that is sour, and an alkali one that has a biting, soapy or soda-like taste. Acids and alkalies unite and form a neutral compound, and then the alkali is called a *base*. The base usually replaces hydrogen in the acid compound. Chemistry, unfortunately, took the common-language terms acid and alkali, and now uses them in a technical or chemical sense, denoting the opposite substances that neutralize each other. *Alkali* and *acid* become complementary or antithetical terms independently of whether the substances have alkali or acid taste. When nitrous acid, HNO_2, and a simple potassium compound are brought together under proper conditions, a new substance is formed, known as nitrite of potash, KNO_2, in which the potash is the base. Nitric acid, HNO_3, under similar conditions, produces nitrate of potash, KNO_3 (saltpeter). This combination of acid and base forms a *salt*. The minimum content of oxygen in a salt is designated by a word that ends in *-ite*, as nitrite, sulfite; the maximum is designated by the suffix *-ate*, as nitrate, sulfate. The corresponding acids end in *-ous* and *-ic:* sulfurous acid forms a sulfite when united with a base, and sulfuric acid forms a sulfate. Plants take most of their nitrogen in the form of nitrates. Examples of well-known salts are chlorid of soda, or common salt, NaCl, the base—sodium—having presumably replaced one atom of hydrogen of hydrochloric acid, HCl; nitrate of soda, $NaNO_3$; sulfate of copper, or bluestone, $CuSO_4$; sulfate of iron, or copperas, $FeSO_4$; sulfate of calcium, or gypsum, $CaSO_4$; tri-calcic phosphate, $(CaO)_3P_2O_5$, the practically insoluble phosphate of bones; di-calcic phosphate, $(CaO)_2P_2O_5$, made by treating bone or phosphatic rock with sulfuric acid, practically insoluble in rain-water but used by roots; mono-calcic phosphate, $CaOP_2O_5$, readily soluble but tending to "revert" in the soil to insoluble forms. These phosphates also contain molecules of water, but these are omitted in the formulas here, so as not to complicate the examples.

The chemical process by which combinations take place is known as a *reaction*. These reactions, or chemical changes, often produce marked visible effects. In fact, the reaction often affords a means of determining what the combining materials are. Often the reaction results in a change of color. Thus, when the blue litmus of lichens is exposed to an acid it turns red; and when this red litmus is exposed to an alkali it turns blue again. This affords a simple and ordinarily satisfactory means of determining the fact of acidity or alkalinity.

The soil is formed by the disintegration of rock, with the incorporation of more or less organic matter. Rock is of very many kinds as regards history, composition and appearance; and the resulting soils are therefore various. A rock may or may not be homogeneous throughout its mass. Some rocks are composites of various *minerals*,—that is, of rock units of definite appearance and usually of definite crystalline structure. Minerals may occur by themselves as more or less large bodies, or their crystals or particles may form part of great masses of rocks. Thus, granite is made up of crystals of several or many minerals, as quartz, feldspar, mica, and others, and the proportions of these minerals differ in different granites. Fig. 451 shows crystals in a certain sample of granite. Crystals or particles of the minerals form an important part of many soils.

CHAPTER X

ORIGIN, CONTENT AND STRUCTURE OF SOILS

SOILS ARE CONSIDERED FROM TWO POINTS OF VIEW in this chapter,—historically as regards their origin and formation, contemporaneously as regards their content, structure and properties. Such discussion is not alone passively informational, for it affords the only enduring basis for active rational treatment of the soil. The untrained reader will be perplexed and possibly even discouraged by the breadth of the discussion; but the closer his reading and the more careful his effort to verify the statements by his own experience, the greater will be the harmony, meaning and delight of any literary treatment that tries to get at the bottom of things. The best treatment of any subject, in the long run, is that which does the subject justice. These remarks are made for the purpose of calling attention again, and yet again, to the fact that all good farm practice rests on an apprehending of underlying principles and phenomena, and that, even as good as the best farm practice of this day may be, it is crude as compared with that which will come when we understand. The best theory of today becomes the practice of tomorrow.

The soil is not a mere inert mixture. Its parts have shape and size and arrangement, as well as being merely composed of certain substances. All these parts have been separately formed, moved and sorted, and then laid together as we find them; and, moreover, they are not even yet at rest, but are always taking new forms and new places and making new partnerships, entailing a never-ending series of mysteries. From the soil all things come; and into it all things at last return; and yet it is always new and fresh and clean, and always ready for new generations. This soft thin crust of the earth—so infinitesimally thin that it cannot be shown in proper scale on any globe or chart—supports all the countless myriads of men and animals and plants, and has supported them for countless cycles and will yet support for other countless cycles. In view of all this achievement, it is not strange that we do not yet know the soil and understand it; and we are in mood to be patient with our shortcomings.

We shall patiently try to understand; and numberless men will give their efforts to this one subject and libraries will be filled with books about it. Just now we shall be content with brief statements of the nature of some of the problems involved; and no man can ever say that any discussion of the soil goes too far or strikes too deep, but rather that it is too brief and too fragmentary. While there are no real lines of clear cleavage, we may yet throw our discussion of the characteristics of soils into three groups: the properties that it exhibits; the substances of which it is composed; the intimate life that it contains. Translated into other words, this means a discussion of it from the physical, chemical and biological points of view. Whether other points of view will develop in time, we can yet scarcely foresee.

The spirit of these remarks is well illustrated in the contemporaneous discussions of soils, for there are wide differences of opinion on questions of scientific fact as well as on farm practice with soils. A cyclopedia cannot enter on the discussion of debatable or controverted subjects, and it cannot take sides, or have an opinion of its own on technical questions; but it can have the subject presented from several points of view by persons who are qualified to speak.

THE SOIL: ITS ORIGIN AND KINDS

By *George P. Merrill*

The earth's crust is composed essentially of mineral matter in varying stages of consolidation, to which the name rock is commonly applied. If the theory of the origin of the earth through cooling and condensation of an incandescent magma be accepted, it follows that the first rocks formed were of a slag- or lava-like nature and, perhaps, in composition unlike any known today. Be this as it may, the true nature of these rocks must always remain a mystery, owing to the manifold changes they have undergone. Some nine-tenths of the land surface is now known to be occupied by rocks of a secondary nature, i. e., of rocks made from materials derived from the breaking down or degeneration of preëxisting rocks. Owing to their mode of formation and structure, such are commonly referred to as sedimentary rocks, or, if through geological causes they have undergone crystallization and other changes, as metamorphic rocks. The remaining one-tenth of the surface, approximately, is composed of igneous rocks, that is, rocks formed through the agency of heat, which have at some time been in a fused or molten condition, and owe their present peculiarities to the effects of cooling.

However varied these rock masses may seem, it is a striking fact that fully 95 per cent of the earth's crust is composed of not over eight or ten of the known elements, and these in comparatively few forms of combination. The eight most important elements with their relative percentages, according to the most recent calculations, are as follows:

Oxygen	47.02	per cent
Silicon	28.06	" "
Aluminum	8.16	" "
Iron	4.64	" "
Calcium	3.50	" "
Magnesium	2.62	" "
Sodium	2.63	" "
Potassium	2.32	" "
Total	98.95	" "

This leaves 1.05 per cent to be made up of all the other elements — the carbon, sulfur, phosphorus, and the metals. Nitrogen does not appear in this table because, while an abundant constituent of the atmosphere, it is almost unknown as an original constituent of the earth's crust.

These facts are still further emphasized in the following descriptions and analyses, which are selected to include only the most important and widespread of rocks. Some details relative to classification, texture and mode of occurrence, are essential to a full understanding of the subject.

Primary rocks.

These are igneous or eruptive rocks which have come from unknown and deep-seated sources in the earth's interior, in a molten condition, and owe their present physical qualities to variations in conditions of solidification and composition. They have as a rule two or more essential constituents. In structure they are massive, crystalline or glassy, or, in certain altered forms, colloidal. The following list includes all the common types. All in the same horizontal line have essentially the same chemical composition, but may differ widely in appearance owing to the degree of crystallization or to other causes. Their mode of occurrence is also noted. As a very general statement, it may be said that those rocks named under neovolcanic (new-volcanic) are of less importance from a soil-making standpoint than the paleovolcanic (old-volcanic) or plutonic. This is so merely because, being geologically younger, they have not been subject to such prolonged decay. Nevertheless, in many parts of the world they have been the chief if not the only sources of soil material.

Intrusive or Plutonic Rocks	Effusive or Volcanic Rocks (Lavas)	
	Paleovolcanic	Neovolcanic
Granite and granite-gneiss	Quartz porphyry	Liparite (Rhyolite)
Syenite	Quartz-free Porphyry	Trachyte
Nephelin syenite	Phonolite	Phonolite
Diorite	Porphyrite	Andesite
Gabbro and diabase	Melaphyr	Basalt
Peridotite	Picrite porphyrite	Limburgite, Leucite and Nephelin Lavas

Regarding these as representing the primary rocks, which have furnished through their degeneration the materials for those classed above as secondary, we may well consider their mineral and chemical composition.

Rocks of the granite-liparite group.—The essential minerals are quartz and orthoclase feldspar, with accessary plagioclase (soda-lime) feldspar, mica, or hornblende, and in small, usually microscopic quantities, apatite and magnetite. It is a wide-spread and important group of rocks. The average chemical composition is shown by the following analysis:

Constituents	Percentage amounts
Silica (SiO_2)	69.80
Alumina (Al_2O_3)	14.45
Ferric oxid (Fe_2O_3)	2.62
Ferrous oxid (FeO)	1.94
Lime (CaO)	1.84
Magnesia (MgO)	0.49
Soda (Na_2O)	3.91
Potash (K_2O)	3.96
Phosphoric acid (P_2O_5)	0.10
Ignition	0.89
Totals	100.00

Rocks of the syenite-trachyte group.—The essential mineral of this group is orthoclase feldspar with hornblende, augite or black mica, and the same microscopic accessories as the granites. The nephelin (elæolite) syenites differ only in that orthoclase is replaced wholly or in part by the mineral nephelin. Containing no quartz and being comparatively richer in the potash mineral orthoclase, or nephelin, the analyses show higher percentages of this valuable constituent. The following are selected as representative:

Constituents	Percentage amounts	
	Syenite	Nephelin syenite
Silica (SiO_2)	63.17	56.85
Alumina (Al_2O_3)	17.82	20.42
Iron oxid (Fe_2O_3)	4.46	5.50
Lime (CaO)	2.49	1.90
Magnesia (MgO)	1.08	0.68
Potash (K_2O)	5.85	6.01
Soda (Na_2O)	4.19	6.91
Phosphoric acid (P_2O_5)	0.10	0.10
Ignition	0.75	1.77
Totals	99.91	100.14

Rocks of the diorite-andesite group.—This group contains many of the so-called trap rocks or greenstones, as well as many lavas. The essential minerals are a plagioclase (soda-lime) feldspar and mica or hornblende, with a plentiful besprinkling of iron oxids and apatite, as well as frequent black mica, augite, and secondary minerals like chlorite and epidote. Like the syenite-trachyte group, explained above, they contain no free quartz, but differ radically in the character of their feldspathic constituent. They are, therefore, relatively poor in silica and potash, and rich in alumina, soda, lime and iron oxids. For this reason, the soils they yield are rarely sandy, but rather of a ferruginous, clayey nature, and not remarkable for their fertility. The same holds true of the rocks of the gabbro-basalt group next to be noted. The figures following in the next column will serve to show the average composition, and afford a basis of percentage comparison with other types, although the group, on the whole, is widely variable:

Constituents	Percentage amounts
Silica (SiO_2)	56.31
Alumina (Al_2O_3)	18.62
Ferric iron (Fe_2O_3)	2.85
Ferrous iron (FeO)	4.96
Lime (CaO)	6.16
Magnesia (MgO)	3.10
Potash (K_2O)	2.56
Soda (Na_2O)	3.93
Phosphoric acid (P_2O_5)	0.40
Ignition and undetermined	1.11
Totals	100.00

Rocks of the gabbro-basalt group.—This group comprises also many of the trap rocks and greenstones and many of the most common lavas, as basalt and melaphyr. The essential constituents are soda-lime feldspars and augite (or some member of the pyroxene group), with the same accessories as the diorites, which they resemble in being poor in silica and potash, and rich in soda, lime, alumina and iron. The following figures, though not the result of an actual analysis, will serve to show the general composition of the entire group:

Constituents	Percentage amounts
Silica (SiO_2)	53.13
Alumina (Al_2O_3)	13.74
Ferric iron (Fe_2O_3)	1.08
Ferrous iron (FeO)	9.10
Lime (CaO)	9.47
Magnesia (MgO)	8.58
Soda (Na_2O)	2.30
Potash (K_2O)	1.03
Phosphoric acid (P_2O_5)	0.40
Ignition and loss	1.17
Totals	100.00

The peridotite-limburgite group.—This group is peculiar in that its members contain no feldspars, being made up almost entirely of iron-magnesian minerals, such as olivine and pyroxene. They are low in silica and alumina, and almost entirely lacking in alkalies, but correspondingly high in magnesia and iron. As soil producers they are of little value, and, fortunately, as rock masses they are comparatively small and unimportant.

Secondary rocks.

The secondary rocks, on the basis of composition, may be divided into two general groups, (1) the silicious and (2) the calcareous. Rocks belonging to these two groups occupy by far the larger part of the earth's surface. From a chemical standpoint they are of an extremely variable nature, in some cases closely resembling the parent masses through the disintegration of which they were derived; or, again, widely differing. Their possible composition may be in part realized if one considers for a moment the method of their formation. A mass of rock, of whatever nature, exposed to the variations of temperature and the chemical action of rainfall (in other words, exposed to weathering), breaks down, as will be described later, into a loose mass of sand, gravel, silt and clay, in which many of the mineral particles are in an advanced stage of decay and from which many of the more soluble salts have been leached. This detrital material is washed by rains into streams, assorted more or less according to the size, shape and weight of the constituent particles, and is finally spread out in essentially horizontal layers on sea-bottoms, to be ultimately consolidated into stone once more and perhaps raised above sea-level, to form a part of the land area. To rocks thus formed are given, according to the size and shape of their particles, the names conglomerate, breccia, sandstone, shale, and argillite or slate. Such vary greatly in chemical composition, as already noted, and with the exception that they are almost invariably poorer in alkalies than the igneous rocks, no general rule can be given. The well-known red-brown sandstone of the Connecticut valley, for example, closely resembles a granite in the proportion of its various constituents, while the buff Berea sandstone of Ohio carries some 85 per cent of silica and less than one per cent of alkalies; and a red carboniferous sandstone from Scotland shows even 95 per cent of silica and is quite lacking in alkalies.

Of the material leached out of the decomposing rock only the lime needs consideration here. This ultimately finds its way into the sea, where, taken up by growing organisms, it forms the shells of mollusks and the stony framework of the corals. On the death of the organism the calcareous portions are broken up by wave action, partially redissolved, and the detritus spread out, in its turn, to become rock masses and a part of the solid land. Thus are formed the great group of calcareous rocks known as limestones and dolomites. Essentially, such are composed of carbonate of lime alone or carbonate of lime and magnesia, but, through impurities, they are rendered silicious, aluminous, or ferriferous. As a rule, they are also poor in alkalies.

Through metamorphism the sandstones and their allies pass into gneisses and the crystalline schists, while the limestones pass into crystalline limestone and marbles. Such from a chemical standpoint differ in no essential particulars from the unchanged sediments. Enough has been said to show the character of the materials from which soils are made. The methods or processes by which they are made are in part physical and in part chemical, but being induced through atmospheric agencies, they are all commonly included under the name of weathering.

The weathering agencies.

The processes involved in weathering, as applied to the phenomena of rock decay, are grouped under two main heads, (1) physical and (2) chemical. The results produced manifest themselves in the general breaking down of a rock into a loosely consolidated mass in which the individual particles are often in an advanced stage of decay, and from which the more soluble constituents have been removed through the leaching action of atmospheric waters. The stability of any chemical compound or mineral aggregate, it must be remembered, is purely a matter of existing conditions. As conditions favorable to a form of combination, deep in the earth's crust, are changed through the cutting down of that crust by erosion and consequent exposure to the air and all its agencies, so a readjustment is brought about, resulting in the formation of new compounds more stable under the new conditions.

This, in brief, constitutes the whole phenomena of rock-weathering, but the details need elaboration.

Atmospheric action.—The nitrogen of the atmosphere, though its most important constituent from the standpoint of bulk, is believed to be almost wholly without effect in promoting rock decay, except, it may be, through the agency of bacteria and other organisms. Oxygen and carbonic acid are the active principles, though the latter exists only in about the proportion of four parts in ten thousand. [See further under Action of Water, page 327.]

Effect of temperature changes.—Rocks are complex mineral aggregates of low conducting power, each constituent of which possesses a ratio of expansion and contraction under the influence of heat and cold, peculiar to itself. Indeed, those minerals composing the major part of the rocks have not merely for each species its own ratio, but a different ratio for each of the crystallographic axes. When the temperature of a rock surface is raised by the sun's heat or by artificial causes, a very complex series of strains is set up. Each mineral tends to expand, and crowds against its neighbor. When cooling takes place, a shrinkage ensues. The amount of movement is slight, so slight, indeed, as at first thought to seem almost trivial, and it is only when time is taken into consideration that the tremendous effects produced can be realized. Slight as is the expansion, it has nevertheless been measured and found to be for granite 0.000004825 inch per foot for each degree Fahrenheit; for marble 0.000005668, and for sandstone 0.000009532 of an inch. The figures may be made more appreciable by applying them to blocks of stone 100 feet in length which, from the extremes of winter's cold and summer's heat, may on the immediate surface undergo a change of temperature amounting to even 150°. Such a change would produce an expansion amounting, in the case of granite, to nearly three-quarters of an inch (0.72). Rocks being but poor conductors of heat, the effect is felt only near the surface; but here expansion finds relief in the direction of least resistance, that is, upwards, and a result manifests itself in the flaking off of thin particles. In cold climates, where glaciation has prevailed, the results of this flaking are sometimes strikingly manifest. Thus, explorers in northern Labrador have brought back sheets of coarse granite of remarkably uniform thickness (about $\frac{3}{16}$ inch) found over areas of many acres, still perfectly fresh, and showing the glacial striæ on their upper surfaces. Almost any of the New England states and the mountain regions of the West will show abundant examples of this form of disintegration, the exfoliation in high altitudes often taking place suddenly with sharp, gun-like reports. The size of the flakes thus loosened varies from those of microscopic dimensions to blocks of many tons weight. Such are conspicuous features of nearly all mountain slopes, and to this cause is largely due the angular and jagged character of mountain peaks.

Disintegration of rock masses in this way is most conspicuous in dry climates and those of great extremes of heat and cold, since here chemical decomposition is reduced to the minimum, while the physical agencies are at their maximum.

Owing to the low conducting power of rocks, disintegration from this cause alone can take place only on the immediate surface, and on flat and level plains where the debris is allowed to accumulate it must in time wholly cease. It is only on hillsides and slopes, or where, by the erosive action of running water or of wind, the material is removed as fast as formed, that such can have any great significance.

Effect of wind.—In arid regions or in any region where the ground is not protected by grass or other vegetation, the wind becomes an important factor in promoting rock disintegration as well as in the transportation of the resultant debris. Particles of sand caught up and driven against rock surfaces exert an abrading power that is surprising when the apparent insignificance of the agent is considered. As the sand grains are lifted but to a slight distance into the air, this agency expends its power in undermining cliffs and boulders, which topple over when the base becomes too small for support. In time an entire outcrop may be thus worn away. Many of the peculiar freaks of the arid landscapes are due to this form of erosion.

Action of water.—Water acts both chemically and physically in promoting rock disintegration. Its chemical activities may be grouped under the heads of (1) oxidation, (2) deoxidation, (3) hydration, and (4) solution, all of which are greatly accelerated through the small quantities of carbonic and other organic acids it may contain. Oxidation manifests itself most conspicuously in rocks containing the sulfids and carbonates of iron, but it is an almost universal accompaniment of any form of chemical decomposition among rocks containing ferruginous silicate minerals, as the micas, amphiboles and pyroxenes. It is this reaction that gives to the soils their brown, yellow and red colors, regardless of the types of rocks from which they are derived.

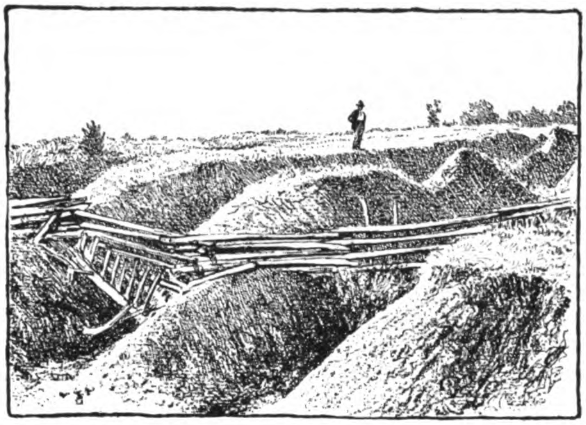

Fig. 453. Excessive erosion of the Clarksville silt loam, Montgomery county, Tennessee.

Deoxidation is as a rule a minor reaction,—rather an accompaniment of certain phases of chemical change than an active agent in promoting it. It manifests itself in the bleaching of rocks colored by ferric oxids, the Fe_2O_3 being converted into FeO and sometimes removed in solution. Soils underlying layers of humus are likewise bleached through the action of the various organic acids.

Hydration (the assumption of water) is an almost invariable accompaniment of decomposition, and it is also a potent factor in promoting disintegration, since with it is involved an increase of bulk which brings a physical action into play. A hydrated mineral, provided there has been no loss by solution, must occupy more space than when in an anhydrous condition.

Solution is, of all the agencies enumerated, the most energetic, though among silicious rocks its action would be greatly limited but for the disintegrating action of heat and cold. Pure water, as long since shown, will partially decompose nearly all the common rock-forming silicates, and its power is augmented through the small amount of carbonic acid it nearly always carries. Carbonate of lime, the material of limestone, is the most

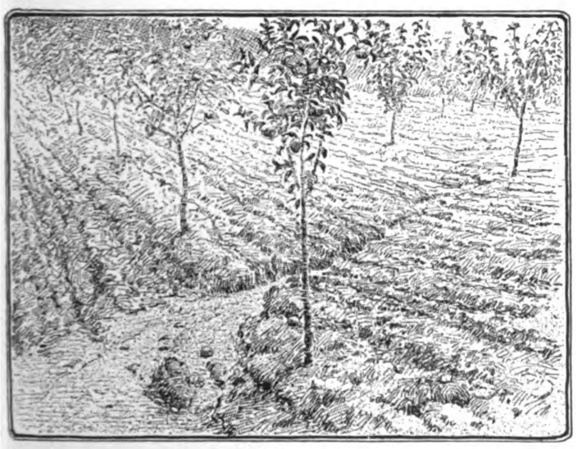

Fig. 452. A delta formed by hillside wash on a soft well-tilled field. Covering for a time with sod may be the best remedy.

readily affected of the common minerals, but none of the essential rock-forming minerals can withstand water action throughout the long periods of time involved in soil formation. This solvent action is shown not merely by the loss of certain constituents in the process of decomposition, but also by the composition of the waters draining any area of decomposing rocks. The following calculations by Sir John Murray, as given by Russell in his work on "Rivers of North America," will serve to illustrate this point:

Constituents in solution	Tons in one cubic mile of water
Calcium carbonate ($CaCO_3$)	326,710
Magnesium carbonate ($MgCO_3$)	112,870
Calcium sulfate ($CaSO_3$)	34,361
Calcium phosphate ($Ca_3P_2O_8$)	2,913
Sodium sulfate (Na_2SO_4)	31,805
Potassium sulfate (K_2SO_4)	20,358
Sodium nitrate ($NaNO_3$)	26,800
Sodium chlorid ($NaCl$)	16,657
Lithium chlorid ($LiCl$)	2,462
Ammonium chlorid (NH_4Cl)	1,030
Silica (SiO_2)	74,577
Ferric oxid (Fe_2O_3)	13,006
Alumina (Al_2O_3)	14,315
Manganese oxid (Mn_2O_5	5,703
Organic matter	79,020
Total dissolved matter	762,587

Analyses of the waters draining any area considered in connection with the annual run-off give figures equally striking. Thus, T. Mellard Reade calculated that, with an annual rainfall of thirty-two inches percolating to a depth of 18.3 inches, there is annually removed by solution from the superficial parts of England and Wales, an average amount of mineral matter of 143.5 tons per square mile of area, while Sir John Murray has calculated that from the entire land surface of the earth 4,975,117,588 tons of mineral matter of all kinds are annually lost.

The mechanical action of water and ice.—Sand driven along by a current of water acts in the same way as when wind-blown, but naturally over a much more restricted surface. It is, however, through such agencies that streams have carved out their channels. It has been shown by actual experiment, moreover, that rock detritus tumbled about, as in a rapidly flowing stream, undergoes not merely a mechanical breaking up, but a certain amount of chemical decomposition as well. Even the impact of water from rainfalls may help to disintegrate and decompose rock surfaces already weakened by heat and frost. Water in the form of glacial ice exercises locally, and during at least one period of the earth's history exercised much more generally, a powerful force to degrade rock surfaces. Through virtue of the sand and boulders frozen into the under sides of these ice sheets the rocks over which they pass are worn down and the abraded material is transported long distances by the aid of water. The ice sheet of the glacial period has left its marks on exposed ledges throughout the northern and eastern United States, and entire landscapes bear testimony, in the form of till and moraine, to its carrying power.

In Fig. 452 (from 1901 report of Bureau of Soils, United States Department of Agriculture) is shown soil washing, or erosion, as it is frequently found in tilled fields.

Frost is another mechanical agency active in promoting soil formation. All rocks are more or less porous and will absorb varying amounts of water. As a rule, the percentage amount, by weight, is small, varying from the half of one per cent in a granite to ten or even fifteen per cent in a sandstone. But water is one of the few substances that expand very materially when undergoing crystallization, or freezing, which in this case is the same thing. One hundred volumes of water, on passing to the condition of ice, expand to one hundred and nine volumes. Obviously, this expansion must find relief, and if confined within the pores of a stone the relief may be found only in forcing the granules apart. This is one of the most fruitful causes of rock disintegration in cold climates.

The action of plants and animals. — Growing plants and, to a less extent, the smaller forms of animal life, aid in the work of rock disruption and decomposition. Even lowly forms of plants, such as lichens and mosses, growing on the rocky ledges, exert a mechanical action by forcing their minute rootlets down into the little crevices opened by heat and frost. The thin film of humus to which such give rise serves further to retain the moisture of rains and supply small amounts of organic acids to help along the chemical side of the work. Larger

Fig. 454. The way in which trees aid in soil formation. The large cracks allow the entrance of rock-weathering agencies.

shrubs and trees send their roots down into preëxisting joints and fissures, which they steadily enlarge through growth, and afford a passageway for surface water with all its entangled gases, and for the action of frost. Fig. 454. Burrowing animals of all classes, the spermophile, badger, and the prairie dog, or insects like the ant, through rendering the

Plate XVIII. Plowing for wheat in New York

surface soil porous and bringing the deeper-lying parts to the surface, exercise in their way an important influence. Even bacteria are by some, particularly French authorities, considered effective promoters of decomposition. In the present state of knowledge it seems probable that they are of greater importance in modifying soils than in their primary production.

Such, briefly outlined, are the chief agencies which are active in reducing the rocks to the condition of soils. For details and minor causes, the reader is referred to more comprehensive treatises on the subject. (See bibliography at end of article.)

Consideration of special cases.

The changes, both physical and chemical, which take place during the process of weathering in some of the more important rocks, will be best understood by reference to the analyses herewith. The original analyses, it should be stated, have here all been recalculated on the basis of one hundred, and from these results those given in the accompanying columns have been calculated.

Reference to these several analyses reveals the fact that among silicious crystalline rocks, represented by the granites, syenites and diabase, there is a loss of constituents amounting in extreme cases to as much as 90 per cent. This high percentage is found, however, only in soils in an advanced stage of decomposition, and in many instances it is doubtful whether the loss has exceeded 50 per cent. With calcareous rocks, on the other hand, there is naturally a much greater loss, amounting in the case of the analysis quoted to 93.63 per cent. Naturally, the amount depends on the purity of the limestone, and in some cases it may amount to even 99 per cent. The analyses also show that among crystalline rocks there is, during decomposition, a loss of silica, a greater proportional loss of lime, magnesia, and the alkalies, and a propor-

FRESH AND DECOMPOSED GRANITE, MERIWETHER COUNTY, GEORGIA.

Constituents	Fresh rock	Decomposed rock	Percentage loss for entire rock	Percentage of each constituent saved	Percentage of each constituent lost
Silica (SiO_2)	69.28	51.03	53.48	22.80	77.20
Alumina (Al_2O_3) . .	16.28	29.54	7.13	56.18	43.82
Ferric oxid (Fe_2O_3) .	1.95	6.30	0.00	0.00	0.00
Lime (CaO)	1.77	0.07	1.74	1.22	98.78
Magnesia (MgO) . .	0.36	0.14	0.31	12.06	87.94
Potash (K_2O) . . .	5.58	1.49	5.11	8.25	91.75
Soda (Na_2O)	4.42	1.12	4.07	7.84	92.16
Ignition	0.36	10.31	0.00	100.00	0. 0
Totals . . .	100.00	100.00	71.84		

FRESH AND DECOMPOSED SYENITE, FOURCHE MT., ARKANSAS.

Constituents	Fresh rock	Decomposed rock	Percentage loss for entire rock	Percentage of each constituent saved	Percentage of each constituent lost
Silica (SiO_2)	59.96	45.81	37.28	37.82	62.18
Alumina (Al_2O_3) . .	18.93	38.18	0.00	100.00	0.00
Ferric oxid (Fe_2O_3) .	4.87	1.36	4.19	13.83	86.17
Lime (CaO)	1.35	0.34	1.19	12.10	87.90
Magnesia (MgO) . .	0.69	0.25	0.57	17.90	82.10
Potash (K_2O) . . .	6.00	0.23	5.90	18.15	81.85
Soda (Na_2O)	6.31	0.37	6.15	2.89	97.11
Ignition	1.89	13.46	0.00	100.00	0.00
Totals . . .	100.00	100.00	55.28		

FRESH AND DECOMPOSED DIABASE, CHATHAM, VIRGINIA.

Constituents	Fresh diabase	Decomposed diabase	Percentage loss for entire rock	Percentage of each constituent saved	Percentage of each constituent lost
Silica (SiO_2)	45.38	36.77	33.41	26.37	73.63
Alumina (Al_2O_3) . .	13.38	13.08	9.11	31.81	68.19
Ferric oxid (Fe_2O_3) .	11.51	35.39	0.00	100.00	0.00
Lime (CaO)	9.84	0.41	9.71	1.32	98.68
Magnesia (MgO) . .	15.28	0.56	15.09	1.19	98.81
Potash (K_2O) . . .	0.47	0.33	0.35	22.69	77.31
Soda (Na_2O)	3.21	1.73	22.64	17.54	82.46
Ignition	0.93	11.73	0.00	100.00	0.00
Totals . .	100.00	100.00	90.31		

FRESH LIMESTONE AND ITS RESIDUAL CLAY, VIRGINIA.

Constituents	Fresh limestone	Residual clay	Percentage loss for entire rock	Percentage of each constituent saved	Percentage of each constituent lost
Silica (SiO_2)	4.13	33.69	0.00	100.00	0.00
Alumina (Al_2O_3) . .	4.19	30.30	0.35	88.65	11.35
Ferric iron (Fe_2O_3) .	2.35	1.99	2.13	10.44	89.56
Manganic oxid (MnO)	4.33	14.98	2.49	42.41	57.59
Lime (CaO)	44.79	3.91	44.32	1.07	98.93
Magnesia (MgO) . .	0.30	0.26	6.25	10.62	89.38
Potash (K_2O) . . .	0.35	0.96	0.23	33.63	66.37
Soda (Na_2O)	0.16	0.61	0.085	46.74	53.26
Water (H_2O)	2.26	10.76	0.95	58.37	41.63
Carbonic acid (CO_2) .	34.10	0.00	34.10	0.00	100.00
Phosphoric acid (P_2O_5)	3.04	2.54	2.73	10.24	89.76
Totals . . .	100.00	100.00	93.635		

tional increase in the amount of alumina and iron oxids, though the apparent increase in the last named may be in part due to a change of the ferrous into ferric oxid.

Soil formation through rock-weathering, then, is a wastefully destructive process, in which, through the leaching action of water, some of the most essential constituents are almost wholly lost. It is apparent, too, though not altogether from the analyses here printed, that, whatever the nature of the rock mass, the soil which results from its prolonged decay will consist essentially of a ferruginous clay.

The physical condition of the residual material, or soil, is no less interesting. A soil resulting from the breaking down of a gneissoid granite in the District of Columbia yielded the following percentages by weight of particles of varying sizes:

Conventional names	Percentages	Diameter of largest grains
Silt	4.25	0.10 mm.
Very fine sand	6.50	0.18 mm.
Fine sand	11.25	0.25 mm.
Medium sand	3.80	0.65 mm.
Coarse sand	63.00	2.00 mm.
Gravel	10.20	8.00 mm.

In this soil the particles called gravel and coarse sand were plainly of a compound nature, aggregates of quartz, feldspar and mica. In the finer material the process of disaggregation had gone so far that many of the particles represented but a single mineral.

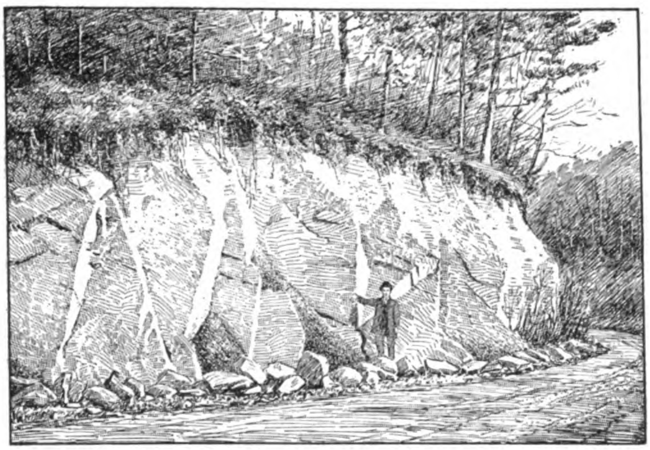

Fig. 455. Rock on which has been formed a layer of soil capable of supporting heavy vegetation.

This material is not, however, in an advanced stage of decomposition, the soil-making process having been more one of disintegration. The rotten diabase from Chatham, Virginia, an analysis of which is given on page 329, yielded the results, under similar treatment, that are given in the following table:

Conventional names	Percentages	Diameter of largest grains
Clay	14.20	0.005 mm.
Fine silt	4.16	0.01 mm.
Silt	23.98	0.05 mm.
Very fine sand	23.49	0.10 mm.
Fine sand	15.39	0.25 mm.
Medium sand	13.10	0.50 mm.
Coarse sand	3.21	1.00 mm.
	97.53	

This soil is of a deep ochreous red-brown color. In the part called clay, none of the original minerals are recognizable. In the silts and very fine sand, feldspar, augite and magnetite can still be occasionally recognized, while the remainder, particularly after treatment with dilute acid, may be readily seen to be of a compound nature.

While, as above stated, the ultimate product of rock decay in general is a ferruginous clay, still, other things being equal, this product will vary somewhat according to the character of the parent rock. This question will be referred to later (page 331).

In Fig. 455 is shown a bed of granite on which has been formed sufficient soil to support vegetation.

What soil is.

All over the exposed part of the globe, and since the very earliest times, rocks have been undergoing decomposition after the manner described. Contemporaneous with decomposition, water of rains and streams has been busy washing the resultant material down the slopes and emptying it into lakes and seas. It is through such processes that the great body of stratified, or secondary, rocks has been formed. Not all of the material, however, passes immediately into the ocean. A comparatively small amount, proportionally a mere film or mantle, remains temporarily on the surface when conditions are favorable. To this layer of comparatively loose clastic material the name regolith (from the Greek, a blanket, and a stone) has been applied, and it is the extreme upper, most highly oxidized and decomposed part of this that forms the soil.

The soil, then, may be defined as the loosely coherent, highly decomposed layer of mineral matter resulting from rock decay, which furnishes food and foothold for plant and animal life. With the soil is almost invariably commingled more or less organic matter, mainly of vegetable origin. Such, however, is but the remains of earlier growths on a soil which primarily must have been wholly inorganic. At times, as in bogs and marshes, soils are met with in which, through favorable conditions of growth and protection from oxidation, the vegetable matter has accumulated far in excess of the inorganic, giving rise to the so-called peaty soils of cold and moist regions.

The depth of the soil cap is variable. It is customary to limit the term to the uppermost part which has been penetrated by roots or agricultural implements, whereby ready access of water and oxidizing agents have been facilitated, resulting in a more thorough decomposition and a higher oxidation of its constituents than in the underlying part, which is known as the subsoil. The difference in color of the soil and subsoil, as well as the degree of compactness, is usually sufficiently marked to render a distinction between the two possible, although it is by no means a hard and fast line and is, as a rule, less pronounced in sedentary than in transported soils.

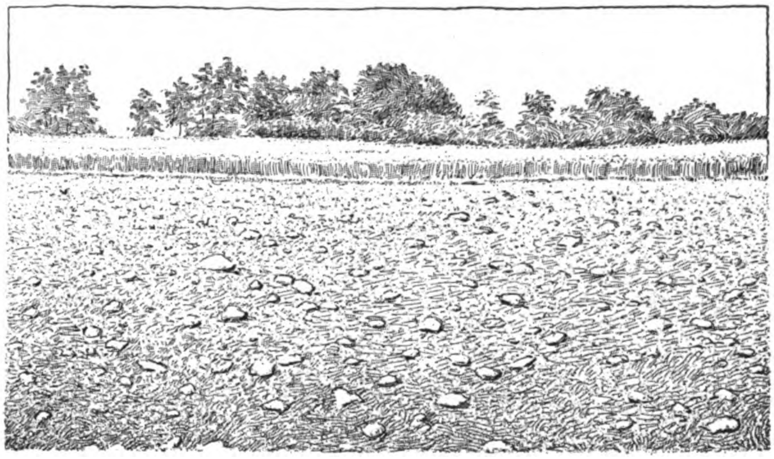

Fig. 456. Triassic stony loam. The stones are picked off, year after year, to provide for cultivation.

The function of a soil is both physical and chemical: physical, in that it gives foothold and support, enabling the plant to retain itself in the position necessary in order that it may perform its functions; and chemical, in that it supplies to the plant such mineral matter—silica, lime, potash, and phosphoric acid—as is necessary for its growth. It was long since shown that few soils are lacking in the essential ingredients, though such may be unavailable through the form of combination or through the physical condition of the soil itself.

Classification of soils.

Because of their ever-varying and intergrading character, a classification of soils according to composition, texture or physical properties, has proved a difficult matter. From a genetic standpoint, i. e., from the standpoint of origin, they may be classed as below: (the same being the plan adopted by the writer in his work on Rocks, Rock-weathering and Soils, though there applied to the entire regolith, only the upper part of which is the soil proper.)

The Regolith	Sedentary	Residual deposits	Residuary gravels, sands, clays, wacke, laterite, terra rossa, etc.
		Cumulose deposits	Peat, muck and swamp or palludal soils, in part.
	Transported	Colluvial deposits	Talus and cliff debris, material of avalanches.
		Alluvial deposits, including the aqueo-glacial	Modern alluvium, marsh and swamp deposits, estuarian clays. Loess and adobe in part.
		Æolian deposits	Wind-blown material, sand-dunes. Adobe and loess in part.
		Glacial deposits	Morainal material, either lateral, terminal, or ground moraines, drumlins, etc.

(1) SEDENTARY SOILS.—Under this name are included those soils resulting from any or all of the processes of rock-weathering or from organic accumulations occupying their original sites. They are the primary types of all soil, since those of drift origin are but derived from sedentary materials through the transporting power of water and ice. They are divided into two classes, (1) residual and (2) cumulose.

(a) *Residual soils.*—Here are included those soils which are the product of rock decomposition in place, i. e., which occupy approximately the position of the rocks from which they were derived and overlie such parts of the same rocks as have escaped destruction. The name is peculiarly appropriate, since they are in reality residues left behind while the more soluble constituents escaped in solution. The prevailing characteristic of an old residual soil is, as already noted, a ferruginous clay. Nevertheless, they often show inherited characteristics such as render them recognizable as derived from certain types of rocks and perhaps suited for special crops. Thus, it has been stated that throughout the central part of Kentucky, where residual soils derived from rocks of several different geological horizons occur, each horizon may be traced long distances, though the rocks themselves are wholly obscured, merely by the character of the forest growth. Obviously, a soil derived from a granite or other rock containing much free silica (quartz) must be sandy or, if thoroughly decomposed, a sandy clay. One derived from a quartzless rock, as a syenite or the trappean rocks, on the other hand, will lack the sandy particles and be more clay-like. A soil derived from a limestone may often be recognized by the characteristic impurities, as chert segregations, which it may contain. Singularly enough, as it may seem at first thought, limestone soils are as a rule quite deficient in lime, even more so than those derived from silicious rocks themselves poor in lime. This, however, is for the very simple reason that the lime-carbonate of limestone is readily removed through the solvent action of percolating water, and only the less soluble impurities remain. It is a striking thought that a single foot in depth of such a soil may represent the loss by solution of ninety-nine feet of rock. The insoluble impurities which go to make up this foot of soil are largely in the nature of quartz sand, clayey matter, or iron oxids, or, if a metamorphic limestone, of quartz and silicate minerals, as mica, tremolite, or pyroxene. A constituent occurring in the minutest quantities may, in such a residual, become a prominent constituent. The celebrated *terra rossa* (red earth) of the Adriatic lands is a residue from a white limestone containing but a fraction of 1 per cent of ferruginous minerals. Residual soils derived from sandstones and argillites may perhaps more closely resemble the parent rock, since derived from rocks which are themselves secondary.

The fine state of division of a residual soil was referred to in the discussion of rock-weathering. It is instructive to note that actual measurements on a given quantity of limestone soil from southern Wisconsin showed it to be composed of:

Particles less than 0.0025 mm. in diameter . . .	721,866
Particles between 0.0025 mm. and 0.005 mm. in diameter	9,812
Particles over 0.005 mm. in diameter	634
	732,312

Mechanical analyses of soils derived from limestone (I and II), sandstone (III), gabbro (IV) and from gneiss (V) are given below:

Diameter of particles	Conventional names	I	II	III	IV	V
mm.		Per cent	Per cent	Per cent	Per cent	Per cent
2 -1	Fine gravel . .	0.54	0.17	0.00	0.00	0.19
1 - .5	Coarse sand . .	0.32	0.00	0.23	1.50	1.80
.5 - .25	Medium sand .	0.72	0.15	1.29	3.49	3.12
.25 - .1	Fine sand . . .	0.62	0.25	4.03	6.24	6.96
.1 - .05	Very fine sand .	4.03	2.34	11.57	11.74	8.76
.05 - .01	Silt	36.02	19.04	38.97	32.60	34.92
.01 - .005	Fine silt . . .	14.99	20.88	8.84	10.77	12.14
.005- .0001	Clay	41.24	51.77	32.70	26.62	28.82
Total mineral matter		98.48	94.60	97.63	92.96	96.71
Organic matter, water and loss.		1.52	5.40	2.37	7.04	3.29
		100.00	100.00	100.00	100.00	100.00

Whitney has calculated that a limestone soil of the nature of the above, containing 45 per cent of material, the individual particles of which vary in size from 0.0001 mm. to 0.005 mm. in diameter, will average 22,000,000,000 particles in each gram by weight, presenting in every cubic foot not less than 158,000 square feet of surface to the action of water, air, and roots of growing plants. The results of chemical analyses of a series of residual virgin soils are scarcely less interesting. Of those given below, I is from a Trenton limestone; II is a Knox dolomite from Alabama; III, a diabase from Wadesboro, North Carolina; IV, a gabbro from Maryland, and V, a Triassic sandstone, also from Maryland:

Chemical Analyses of Residual Soils.

Constituents	I	II	III	IV	V
Silica (SiO_2)	71.13	55.42	39.55	66.27	55.39
Alumina (Al_2O_3) . .	12.50	22.17	28.76	15.25	20.16
Ferric oxid (Fe_2O_3) .	5.52	8.30	16.80	6.97	8.79
Ferrous oxid (FeO) .	0.45				
Titanium oxid (TiO_2)	0.45	0.00	0.64	0.00	0.00
Phosphoric acid (P_2O_5)	0.02	0.00	0.10	0.07	0.04
Manganese (MnO) . .	0.04	0.00	0.00	0.00	0.00
Lime (CaO)	0.85	0.15	0.37	0.24	0.51
Magnesia (MgO) . .	0.38	1.45	0.59	0.43	1.27
Soda (Na_2O)	2.19	0.17	trace	0.40	0.79
Potash (K_2O) . . .	1.61	2.32	trace	0.86	4.03
Water (H_2O)	4.63	9.86	13.26	8.20	7.38
Carbonic acid (CO_2) .	0.43	0.00	0.00	0.00	0.00
Carbon (C)	0.19	0.00	0.00	0.00	0.00
Totals . . .	100.39	99.84	100.07	98.69	98.36

Residuary soils derived from limestone may be found to pass abruptly into fresh, sound rock, but there is more commonly a thin transition zone of more or less shattered and discolored matter. The reason for this lies in the fact that the transformation is mainly by solution, which acts only on exposed surfaces and along lines of weakness, as joint and shearing planes: this process does not extend deep. The result depends very much on the degree of homogeneity of the parent rock and its freedom from flaws. Soils derived from silicious rocks, on the other hand, nearly always show a broad transitional zone of intermediate products, beginning with the coarser materials immediately underlying the soil proper and passing downward with an ever-increasing proportion of stony matter, until massive blocks of undisturbed rock are reached, scarcely at all discolored or decomposed, though traversed, it may be, by complicated lines and vein-like fissures of decomposed material. The reason for this, too, is obvious: the silicious rocks possessing a relatively large proportion of insoluble matter, the transformation into soil is largely a matter of disintegration.

Residuary soils, as a rule, are more highly colored than those belonging to the "transported" group, the color being due not alone to the amount of iron oxid, but to the form, as well. The subject is one over which there has been considerable discussion, but the prevailing opinion is to the effect that the difference in color is due to a natural dehydration (loss of water) which takes place in the warmer regions where these soils prevail, whereby the hydrous sesquioxides of the type of limonite and göthite pass over into the less hydrated and more brilliantly colored forms, hematite and turgite. This view is rendered the more plausible from the fact that the brilliant hues are quite superficial and, excepting where the soil is very ancient and thoroughly decomposed throughout, fade out to browns and grays below.

From what has gone before, it would appear that the character of a residual soil is dependent, not more on the character of the parent rock than on climate. In an arid region the breaking down of rocks is mainly mechanical and the particles rarely reach the condition of a clay—the soils are sandy or gravelly. In regions of frost, even though there be an abundant precipitation, mechanical agencies still predominate, decomposition proceeds slowly, and the oxidation of ferruginous compounds is retarded. Hence soils of cold, moist regions, though they may be in a highly comminuted condition, are rarely highly colored. The soils of moist, warm regions, on the other hand, are in an advanced stage of decomposition, often reduced to the condition of clays, and highly colored, through the peroxidation of the iron content and its partial dehydration.

(b) *Cumulose soils.*—Soils of this type result from the accumulation of organic matter by growth and decomposition in place. They pass by imperceptible gradations into certain types of alluvial soils, as will be noted later. Their origin and nature are nowhere better illustrated than in the lake and bog region of New England. Glacial drift, by damming the streams, caused them to expand into numberless shallow lakes. As the ice sheet withdrew, the streams slowly cut down through the glacial debris, and the lakes were gradually drained. But, contemporaneous with the drainage, there developed a prolific growth of confervoid plants, mosses, and the like, extending gradually outward from the shore, until in extreme cases forming a complete carpet over the surface. More commonly, however, through a breaking away and sinking of the material around the edges, the lake became filled with the spongy mass of partially decomposed organic matter. Throughout the region mentioned, and particularly in Maine, are thousands of bogs, occupied it may be with a dense growth of bushes about the margin, and with perhaps a shallow mud lake in the center, the intervening part a level expanse of sphagnous mosses interspersed with pitcher plants, orchids, and all manner of swamp vegetation, over which during dry seasons one may walk with safety, but which, in wet seasons, are dangerous in the extreme. Such are the well-known quaking and peat bogs of Ireland and Scotland. Soils of this type may be largely silicious along the shores, but grow less and less so as the shore recedes, until near the center they are almost wholly organic. This is well shown by the following analyses of soils from a swamp near Beaufort in North Carolina:

Constituents	Margin	Center
Silica (SiO_2)	84.54	1.52
Alumina (Al_2O_3)	2.69	0.39
Ferric oxid (Fe_2O_3)	1.18	0.15
Lime (CaO)	0.44	0.36
Magnesia (MgO)	0.22	0.14
Potash (K_2O)	0.07	0.06
Soda (Na_2O)	0.02	0.13
Phosphoric acid (P_2O_5)	0.08	0.06
Sulfuric acid (SO_3)	0.06	0.00
Chlorin (Cl)	trace	0.02
Organic matter (C)	7.70	87.25
Water (H_2O)	2.50	9.60
	99.50	99.68

Soils of this nature are dark, deep brown to black in color, and until drained and oxidized through plowing, sour and unfit for cultivation. They are of enormous extent in other regions than those mentioned, and the vegetation is not always of a sphagnous nature. Throughout the Kissimmee valley of Florida are thousands of acres of swamp and bog which are rapidly filling and which, by draining, may be sometime available. As soils, deposits of this nature are of less importance than those which result from the combined processes of plant growth and sedimentation and which are described under the name alluvial (page 334).

Fig. 457. Memphis silt loam, showing excessive erosion. A considerable part of the cone-hills region is badly eroded, even on the gentlest slopes, gullies with nearly vertical walls 15 to 30 feet high eating up into the cultivated land with remarkable rapidity. The only effective way to prevent this seems to be reforestation or the growing of a covering of Bermuda grass or lespedeza.

(2) Transported soils.—Erosion is an almost constant accompaniment of decomposition. To the geologist the fact that the process has gone on in past ages is proved by the thousands of feet of secondary rocks, and by the upturned edges of eroded

strata. That erosion is still going on, and that, too, at a rapid rate, is shown by the muddying of streams after rains and by gullied fields and hillsides. The decomposed material is not, however, transported altogether and at once to the sea, but some is spread out over valley bottoms and wherever conditions are favorable, to form soils. Naturally, in the process of transportation of materials loosened by decay there is likely to be a considerable commingling of materials from diverse sources. Naturally, too, when the transporting agent is either wind or water, there is likely to be an assorting of particles according to shape, sizes and specific gravity, so that an alluvial soil will show a more or less distinct stratification, the individual beds or layers of which will be of a more homogeneous nature than in a soil that is residual.

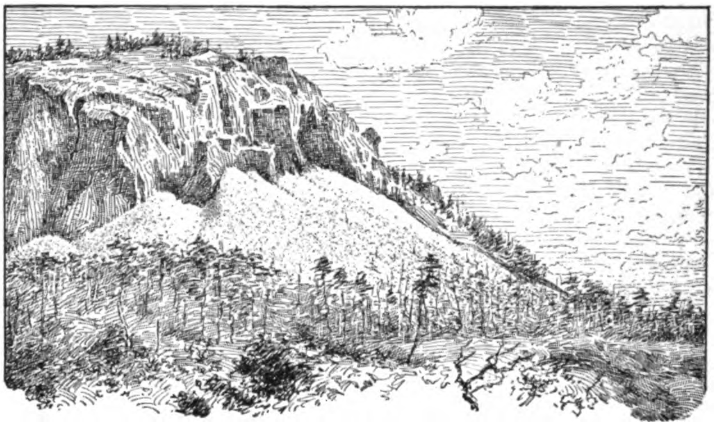

Fig. 458. Process of erosion of rather soft rock, the talus from which is invading forest land.

According to the classification adopted above, the transported soils are divided into (1) colluvial, (2) alluvial, (3) æolian, and (4) glacial.

(a) *Colluvial soils.*—Under the name of colluvial (from the Latin *colluvies*, a mixture) are included the heterogeneous aggregates of rock detritus occurring on mountain slopes and steep hillsides and commonly designated as talus and cliff debris, and also the even more heterogeneous deposits brought into valleys in the form of avalanches. In the transportation of these deposits gravity has been the controlling factor, and there is little assorting of material—mud, sand, gravel and boulders of many tons weight all commingled. The individual particles in such a deposit are angular and rarely in a condition of advanced decay. Fig. 458 illustrates these features. From an agricultural standpoint such soils are of little importance, though along their lower margins they may pass into those of the next group.

(b) *Alluvial soils.*—So universally is the carrying power of water exercised that few areas escape its action, and soils due to water transportation and redeposition are more wide-spread, extensive, and of greater importance than any and perhaps all others combined. In many instances the distance of transport is short,—it may be but down the steep hillsides into the valley bottoms. Such naturally grade upward into the colluvial described above. Again, the material, by temporary rivulets and the larger streams, is carried seaward to be spread out in delta form, as at the mouths of the Nile and the Mississippi. It is a well-known principle of geology that the carrying power of a stream increases as the sixth power of the velocity of the current. Given, then, a stream loaded with detritus, as, for instance, the Mississippi in seasons of flood, and cause its current to be checked, and a deposition of part of its load will result. Such a checking takes place when a stream, during stages of high water, overflows its banks and spreads out over the level flood plains on either hand. Each year or each season of flood adds to the deposit, until such a height is reached that the river, the channel of which is being constantly deepened, no longer overflows it, and the flood plain becomes available for cultivation. (Fig. 459.) The flood plains of the Mississippi river are stated by Russell to be 50 to 60 miles in breadth and to comprise an area of some fifty thousand square miles.

Another phase of alluvial deposition is that shown in many a small lake throughout the glaciated areas. The entering streams bring from the adjacent hills sand, mud and organic matter which is deposited in the form of a broad, flat, alluvial fan almost as soon as the waters commingle. Each year the shallowing spreads farther and farther into the lake; reeds and other aquatic plants lend their aid; and in a comparatively brief period of time there is formed an almost perfectly level plain traversed by a sluggish meandering stream. This condition is shown in Figs. 460 and 461. There is a close connection between soils thus formed and

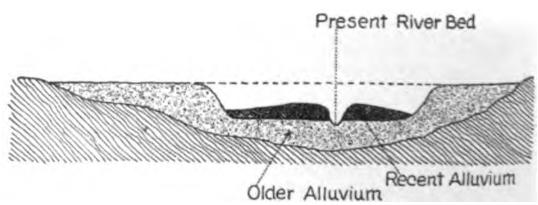

Fig. 459. Generalized section across the Mississippi river, showing alluvial deposits. (After Le Conte.)

much of the cumulose deposits just described and of the loess discussed on page 336.

But not all the detritus carried by a river is left on its flood plains. A portion, and a preponderatingly large proportion, is carried down to its mouth and poured into the sea. Under ordinary conditions of load and tide this material is carried away from the immediate proximity of the river mouth and spread out over the sea-bottom. In cases of extraordinarily large quantities of detritus, or more commonly through a deficiency of tide and wave action, as in the Gulf of Mexico and the Mediterranean, the detritus accumulates immediately about the river mouth, forming in time extensive mud and sand flats, the upper surfaces of which are ever below the limits of high water. These form the deltas for which the rivers mentioned are celebrated. The nature of a delta deposit varies according to the character of the country drained and the carrying power of the river. Naturally, however, a large share of the mineral matter is in a fine state of subdivision. An appreciable amount of vegetable matter is a constituent of most delta soils. A microscopic examination of the materials of the Nile delta revealed the presence of rounded and subangular grains of quartz and feldspar, with particles of augite, hornblende, and smaller quantities of mica, tourmaline, sphene, zircon, fluorspar and magnetic iron. A lack of kaolinic decomposition products led to the conclusion that these constituents had been derived through the breaking up of the original rock masses by heat and frost, rather than by decomposition.

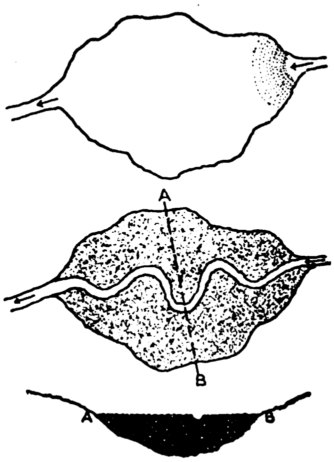

Fig. 460. Two ground plans and cross-section illustrative of the filling of a small lake by sedimentation.

McGee has described the delta of the Mississippi as at once the most extensive and most complete example of a land surface lying at base level, or a trifle below, that America affords. The whole surface lies so low that it is flooded by periodic overflows of the streams, and each flood adds a coating of river sediments. Much of this flood plain, thus fertilized, is clothed with luxuriant forests and dense tangles of undergrowth, or cane, and more rarely grasses. Partly by reason of this mantle of vegetation, the current of each overflow is checked as the streams rise above their banks, and most of the sediment is dropped near by as a result. For this reason, all the rivers are flanked by natural levees of a height and breadth proportional to the depth and breadth of the stream. The network of waterways becomes thus a network of double ridges with channels between, and each intervening space is a shallow pond in which the waters of the flood lie long. In the outermost part of the delta, such lie so near tide level as to become converted, for the time being, into salt marshes.

Though soils of the delta type may be fertile in the extreme, they may also be well-nigh barren.

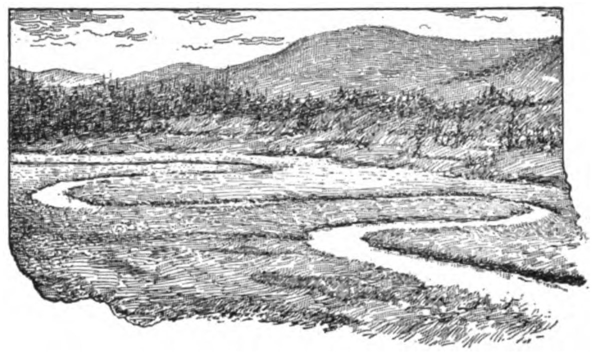

Fig. 461. Stream in the Adirondacks meandering through a filled lake plain.

The "black prairies" of Arkansas and Louisiana are of delta origin, but so poorly drained and of such fine materials that only coarse grasses will grow on them.

Still another illustration of the formation of alluvial deposits is that given by Shaler in his discussion of the sea-coast swamps of the United States. The formation of these swamps is brought about through the action of waves aided by growing plants. Wherever, owing to indentations of the coast, or through other causes, the strength and consequent carrying power of the tide is deadened, the sediment from rock disintegration along the shores or brought down by streams is deposited. As soon as a layer of mud of sufficient thickness is formed, a dense growth of eel-grass comes in, which still further checks the carrying power of the tide and helps to retain the debris that would otherwise be carried seaward. When, through these causes, the sea-bottom has been raised above the limit of growth of eel-grass, other and higher types of vegetation appear, until a level is reached where it is covered only by the highest tides, and growth practically ceases except through the accumulation of vegetable matter. Such are the salt-water marsh soils so extensive along the Atlantic coast. So long as they remain subject to inundation by high tides, they yield only coarse grasses and sedges, but when cut off from the salt water by dams and dikes, they become fertile. Fig. 462 shows diagrammatically the origin and structure of marsh soils.

Professor Shaler estimates that there are 200,000 acres of reclaimable soils of this type between New York and Portland, Maine, and probably over 3,000,000 acres on the entire Atlantic coast; and according to Marr, some 7,000 acres were gained from the sea in the Portmadoc estuary of Wales near the beginning of the last century.

Soils of the alluvial type, as above noted, are stratified, and the varying strata are subject to a considerable range in texture and composition. As a rule, however, the particles composing them are moderately fine, perhaps impalpably so, much depending on the conditions under which they were deposited. The table below gives the results of mechanical analyses of selected soils of this type. Particular attention is called to the remarkable degree of comminution which the material has undergone:

APPROXIMATE NUMBER OF GRAINS OF MINERAL MATTER IN ONE GRAM OF ALLUVIAL SUBSOIL.

Diameter in mm.	Conventional names	Locality: *Rockford, Ill.	Locality: †American bottom
2 -1	Fine gravel . . .	1	0
1 - .5	Coarse sand . . .	48	0
.5 - .25	Medium sand . .	3,428	5
.25 - .1	Fine sand . . .	29,300	194
.1 - .05	Very fine sand . .	212,400	151,400
.05 - .01	Silt	5,888,000	12,230,000
.01 - .005	Fine silt	115,100,000	195,600,000
.005- .0001	Clay	3,842,000,000	14,680,000,000
	Totals	3,963,233,177	14,887,981,599

*Flood plain deposit. †Bottom lands of the Mississippi.

There are two varieties of soils belonging to the alluvial class which, owing to their wide geographic distribution and general importance, are worthy of an extended notice. These are the soils commonly known under the names loess and adobe.

The loess, as first described by European authorities, consists of a fine buff or yellow silt, or loam, so slightly coherent as to be readily crushed between the thumb and fingers and yet possessing sufficient tenacity to resist the ordinary action of the atmosphere and stand with nearly vertical walls when cut through by the erosive action of streams or by other means. The material has a wide distribution throughout Europe and still wider in China, the entire area covered continuously being stated as equal to all of Germany, while it is found in detached areas over an additional area nearly one-half as large. In the United States, loess occupies thousands of square miles of territory throughout the drainage basin of the Mississippi river. As first described, the European and Chinese loess was regarded as mainly a wind-drift deposit, that is, a deposit formed through the gradual accumulation, under favorable conditions, of fine particles of mineral matter drifted by the wind, as described under æolian deposits (p. 338). A similar origin is ascribed to the Russian loess, though the fact is recognized that much of the original material has been redistributed by running water and by the wind. The celebrated black earth, or *tchernozem*, is a loess blackened by vegetable matter. Recent studies, however, have tended to modify these views and to show that much of it, particularly in America, is of alluvial origin, though superficially modified by wind erosion. Such is probably the origin of the loess of the Mississippi valley, where it covers areas of thousands of square miles to depths of 5 to 150 feet, furnishing soils of great strength and fertility. The material here is considered by the best authorities as representing the fine silt brought southward by streams formed by the melting ice of the glacial period and deposited in then existing lakes of fresh water. The material is of wonderful uniformity of texture. The microscope shows the mineral particles to be fresh and angular, indicating that they are a product largely of mechanical trituration rather than chemical decomposition. The following analyses are chosen to show both the composition and texture:

CHEMICAL COMPOSITION OF LOESS.

Constituents	Dubuque, Iowa	Vicksburg, Miss.	Valley of the Rhine	Neubad, Switz.
Silica (SiO_2)	72.68	60.69	58.97	71.09
Alumina (Al_2O_3) . . .	12.03	7.95	9.97 }	
Iron sesquioxid (Fe_2O_3) .	3.53	2.61	4.25 }	16.78
Iron protoxid (FeO) . . .	0.96	0.67	0.00 }	0.00
Titanium oxid (TiO_2) . .	0.72	0.52	0.00	0.00
Phosphoric acid (P_2O_5) .	0.23	0.13	0.00	0.11
Manganese oxid (MnO) .	0.06	0.12	0.00	0.00
Lime (CaO)	1.59	8.96	11.31	1.81
Magnesia (MgO)	1.11	4.56	2.02	0.00
Soda (Na_2O)	1.68	1.17	0.84	1.23
Potash (K_2O)	2.13	1.08	1.11	1.30
Water (H_2O)	2.50	1.14	1.37	1.96
Carbonic acid (CO_2) . .	0.39	9.63	11.10	0.80
Sulfurous acid (SO_2) . .	0.51	0.12	0.00	0.00
Carbon (C)	0.09	0.19	0.00	2.87
Totals	100.21	99.54	100.94	97.95

MECHANICAL ANALYSES OF LOESS.

Constituents	Upland loess Virginia City, Illinois	River loess Virginia City, Illinois	Loess Nebraska
	Per cent	Per cent	Per cent
Moisture	0.00	0.00	5.40
Organic matter	0.00	0.00	4.96
Gravel	0.00	0.00	0.00
Coarse sand	0.00	0.00	0.00
Medium sand	0.00	0.00	0.00
Fine sand	0.01	0.10	0.00
Very fine sand	7.68	24.84	23.14
Silt	61.85	60.98	54.81
Fine silt	9.60	2.80	2.46
Clay	15.15	6.15	9.45
Totals	94.29	94.87	100.22

The name adobe is given to a somewhat variable material which forms the surface soil throughout many thousands of square miles of the region west of the Mississippi and which, like the loess, is easily pulverized and yet possesses sufficient coherence to stand in the form of vertical escarpments. Molded in brick-like pieces and sun-dried, it is used as building material by the Indians and Mexicans. It may be best described as a calcareous clayey loam of a prevailing gray-brown color, which has been derived mainly by a process of mechanical disintegration from the surrounding mountains and swept by winds and rains, with a minimum amount of decomposition, into the valleys and lowlands. The name, unfortunately, like most soil names, has no exact significance and is made to include materials of diverse origin, a part of which is seemingly almost identical with some forms of loess. As already noted, adobe forms the soil over thousands of square miles of the more arid sections of the West, occurring at all elevations up to six or eight thousand feet, and of a known maximum thickness of two to three thousand feet. In its typical form it possesses little, if any, more grit than the loess, and shows under the microscope its individual particles fresh and sharply angular, varying in size from 0.08 mm. in diameter down to sizes too small for measurement. Being a product of arid land disintegration, rather than decomposition, and having since its formation been subjected to a minimum amount of leaching, the adobe is naturally richer in alkalies and the alkali earths than are soils of a residual nature. This feature is brought out in the analyses following:

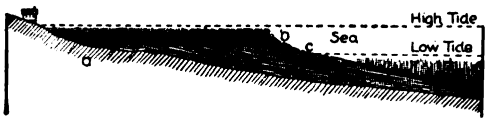

Fig. 462. Diagrammatic section showing the origin and general structure of marine marshes. *a*, original surface at shore line; *b*, grassy marsh; *c*, mud flats; *d*, eel-grass; *e*, mud accumulated in eel-grass growth.

CHEMICAL COMPOSITION OF ADOBE SOILS.

	Santa Fé, New Mexico	Humboldt, Nevada
Silica (SiO_2)	66.69	44 64
Alumina (Al_2O_3)	14.16	13.19
Ferric oxid (Fe_2O_3)	4.38	5.12
Manganese oxid (MnO)	0.09	0.13
Lime (CaO)	2.49	13.91
Magnesia (MgO)	1.28	2.96
Potash (K_2O)	1.21	1.71
Soda (Na_2O)	0.67	0.59
Carbonic acid (CO_2)	0.77	8.55
Phosphoric acid (P_2O_5)	0.29	0.94
Sulfuric anhydrid (SO_3)	0.41	0.64
Chlorin (Cl)	0.34	0.14
Water (H_2O)	4.94	3.84
Organic matter	2.00	3.43
	99.72	99.79

The fine clay particles washed from the morainal drift and redeposited in the estuaries marking the close of the glacial epoch now form the compact, highly plastic blue clay so commonly used for brick-making and the coarser forms of pottery. In places, this forms also the surface soil, but its extreme plasticity when wet, and compactness when dry, makes it undesirable unless mixed with a considerable amount of other material. Such soils contain fairly high percentages of lime, potash and phosphoric acid, and are lacking in fertility only because of their physical properties. Superficially, they become oxidized to a buff or gray-brown color, but are uniformly blue-gray below.

Immediately overlying these clays, and often covering extensive areas quite independent of them, are deposits of fine, loose, silicious sand which are likewise a product of the re-assortment of morainal material by water. These form the frontal aprons and overwash plains of the geologist and afford the only substitute for soil of many a "pine flat" forest in New England. The material is too light and deficient in available food ingredients to make a cultivable soil excepting during wet seasons.

It has sometimes happened that the processes of erosion and sedimentation as effected by rivers have resulted in the accumulation on recent ocean bottoms of large areas of mud, sand and gravel, which have been re-elevated to form land areas, with little, if any, induration, and which are ready almost at once to assume the functions of soils. Indeed, in many respects such closely simulate alluvial soils, except that at an earlier period they were laid down on sea or estuarian bottoms rather than on the flood plains of rivers. Deposits of this nature form the so-called "coastal plain" of the American geologists, a flat, marginal belt of clay, sand and gravel extending from New Jersey to the Rio Grande, and comprising altogether some 400,000 square miles of territory. This is made up, so far as the superficial parts are concerned, wholly of fragmental materials which in Tertiary times were brought down by rivers and spread out over areas now land, but then depressed beneath the level of the Atlantic ocean and the Gulf of Mexico. Primarily a flat and level plain, it has been trenched and is now being base-leveled by the seaward extension of the very streams that gave it birth. Nowhere does it rise more than a few hundred feet above sea-level, and for a considerable part of its area has so slight an elevation as to cause it to be known as the "flat lands." Geologically, the superficial beds or strata forming the coastal plain have been divided into the Potomac (the oldest), the Sabine, the Claiborne, the Vicksburg, the Grand Gulf, the Lafayette and the Columbian. Of these, the last two only need consideration here, and the Lafayette is of the greater importance.

Originally the Lafayette overlay nearly the entire coastal plain, but now, through erosion, it covers little more than half that area. Genetically, it is a littoral deposit, an extensive sheet of loam, sand and gravel of such physical consistency as, on the whole, to make a fairly fertile soil. Locally, it varies greatly in color with perhaps a prevailing yellow hue that has caused it to be known throughout Mississippi and adjacent areas where strongly developed, as the "orange sand." The material of which it is composed varies, as does that of the Columbian formation, and indeed, as may be readily imagined, according to the character of the sediments brought down by the rivers — the Potomac, Susquehanna, Tombigbee, Arkansas, and others—to which it owes its origin. At times it is a clay, then a true loam, now a sand and again a coarse gravel, scarce worthy the name of soil.

The Columbian formation, which shares with the Lafayette a large part of the surface area of the coastal plain, consists of a sheet of brown, clayey loam, passing downwards into beds of coarse gravel composed largely of pebbles of quartz and quartzite. Near the inward edge of the deposit it is naturally coarser, but at a greater distance from the old shore line it becomes finer and culminates as a true loam at a distance of not more than three or four miles from this line. In the District of Columbia, the material consists mainly of silicious pebbles in a sandy clay, which, during seasons of drought, becomes greatly indurated, forming a very poor soil. Like the Lafayette, which in places it overlies, it is variable in both its mineral nature and physical characteristics. Owing to the great thickness of these deposits and their loosely consolidated condition, the soils of both formations wash badly, and in many parts of the South where sufficient care has not been taken to prevent, thousands of square miles of arable land have been wasted and lost beyond all recovery, so far as man is concerned.

(c) *Æolian, or wind-drifted soils.*—In arid and semi-arid regions, the wind often exerts an important influence on the character and distribution of the soil. The possible æolian origin of the loess has been already referred to, and it is very probable that even should it be shown that a large share of the loess of both continents is of alluvial origin, a very considerable part of it, and particularly that of the higher altitudes, may be of wind-drifted material. The usual action of the wind, in a region not protected by vegetation, is to lift and transport the lighter particles, sometimes in the form of dust clouds, carrying them long distances to lay them down once more where, through a failing of the wind, the protecting action of vegetation, or through other causes, conditions are favorable. True dust soils are not unknown in the extreme West. Such are characterized by the extreme fineness of their particles. A more common, or, at least, more noticeable result of wind action is the production of dunes, as happens in cases when the soil particles are too heavy to be lifted bodily by the wind and carried for any distance, but are rather trundled along close to the ground. The action of the wind is such that there is a tendency for the material to gather in drifts, like snow, to which the name dune is applied. (Fig. 463.) Such, under the goading influence of the wind, are continually advancing, and as they are composed mainly of silicious sand, too light and too porous to permit of a ready growth of vegetation, they are at times productive of much harm in overwhelming cultivated fields, forests and even villages. Fig. 464 shows the encroachment of a sand-dune on an orchard; there is nothing to prevent its overwhelming the entire orchard in time. Sand thrown by waves on the beaches of lakes and oceans is often handled by the winds in this way, as are

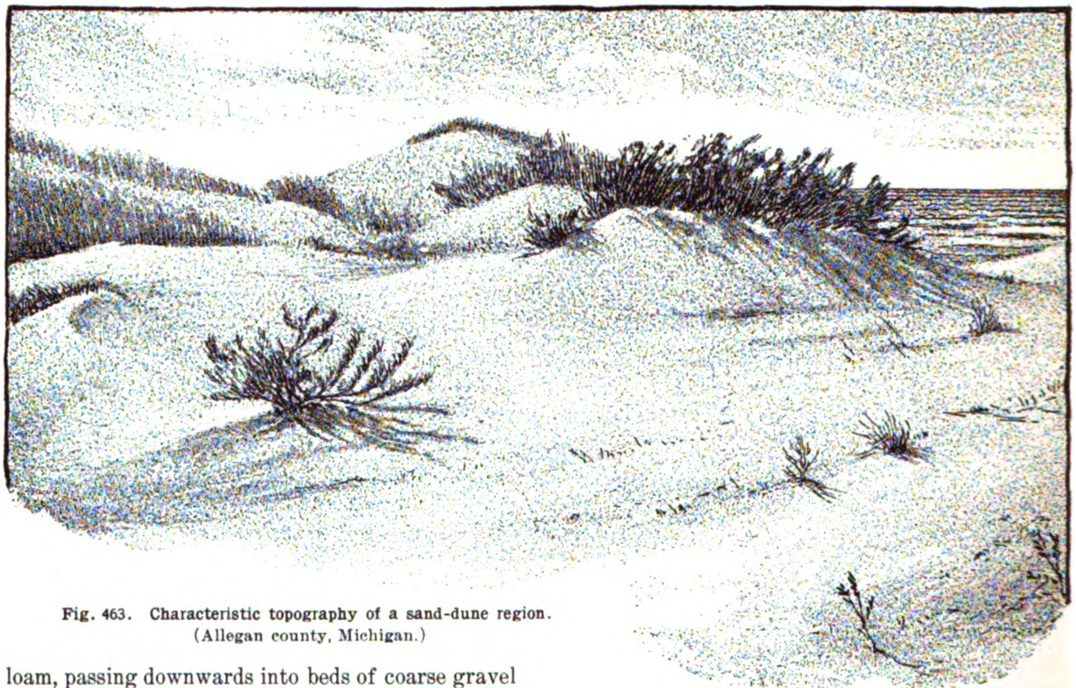

Fig. 463. Characteristic topography of a sand-dune region. (Allegan county, Michigan.)

also the sands of desert regions generally. Such soils need not necessarily be infertile, but because of their mobility vegetation gets a hold but rarely and even then may be choked out by drought, to which so light a soil is more than liable.

The finely pulverulent material blown from volcanic throats during periods of explosive activity falls again, sometimes in the immediate vicinity, or is drifted along by the wind to varying distances. The amount of this material, known commonly under the names of volcanic sand, ashes and dust, is at times very great and may cover the land for miles around in such quantities as quite to blot out whatever vegetable life may have previously existed. In the volcanic region north of Flagstaff, Arizona, are extensive areas almost bare of vegetation except for scattered pines, the entire surface being covered with fine lapilli resembling nothing more than crushed coke. The material, though ejected some hundreds of years ago, is still too fresh and coarse to form a soil, as the word is ordinarily used. The late eruptions of Pelee on the island of Martinique afford an illustration, still fresh in the mind, of the renewal of soil through dust showers. During the eruption of St. Vincent in 1812, dust like a "slow, silent rain" fell for hours on the Barbadoes islands nearly a hundred miles distant, covering the ground to a depth of several inches with a black, fertilizing dust.

(d) *Glacial deposits.*—Material transported by glacial ice and deposited in the form of medial, terminal or lateral moraines, or as till or ground moraine, forms no inconsiderable part of the soil throughout New England and the Northern, Middle and Central states. Soils of this nature are rather heterogeneous. With the exception of the ground moraine, they represent the material fallen on the surface of the ice and transported varying distances, to be laid down in the form of loose piles of sand, gravel and boulders, when the ice sheet finally retreated. Such deposits appear on the surface as more or less rounded, dome-shaped hills or long ridges, and are known under a variety of local names, as osars, kames, horsebacks, drumlins and others. (Fig. 465.)

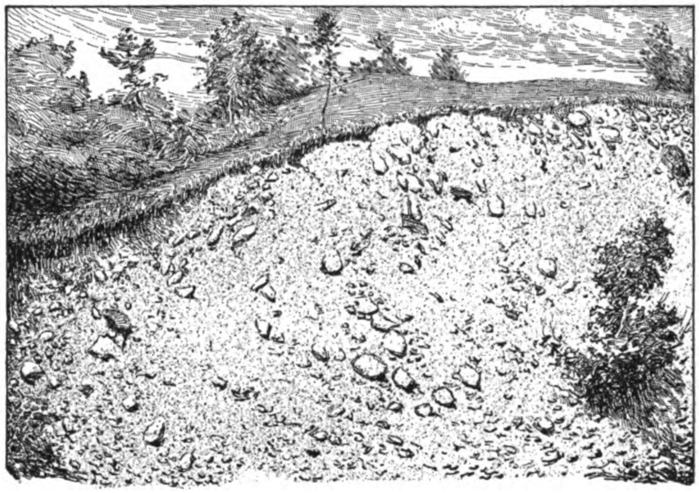

Fig. 465. Partial section of a moraine near Whitewater, Wisconsin.

The lithological nature of their materials is variable, and consists of more or less rounded boulders imbedded in a loose sand or gravel. Soils of this type are usually light and often poor. The soil of the ground moraine or till is of a very different type. This is the stony material pushed and dragged along beneath the glacier, and consists of more or less angular and rhomboidal boulders of fresh rock imbedded in a dense blue-gray clay, which may be so hard a short distance below the surface as to be quite impervious and form a so-called hardpan. The boulders differ from those in the deposits described above in that they are scratched and scarred and show other signs of the hard usage they have undergone. The clay in which they are imbedded and which forms the soil proper is a true rock flour, a product largely of mechanical action rather than decomposition. The following table, from the work of Mr. F. Leverett, as quoted by Dr. Milton Whitney, shows the approximate number of grains in some Illinois till soils, from which the larger boulders and pebbles had been removed:

Fig. 464. The encroachment of a very high sand-dune on an orchard. Allegan county, Michigan.

APPROXIMATE NUMBER OF GRAINS IN ONE GRAM OF GLACIAL TILL FROM ILLINOIS.

Diameter in mm.	Conventional names	Localties		
		Charleston	Marshall Co.	Champaign
2 -1	Fine gravel	0	3	2
1 - .5	Coarse sand	7	31	28
.5 - .25	Medium sand . . .	284	959	955
.25 - .1	Fine sand	2,567	13,660	8,753
.1 - .05	Very fine sand . . .	73,480	239,600	104,100
.05 - .01	Silt	13,530,000	6,816,000	7,907,000
.01 - .005	Fine silt	238,100,000	206,000,000	276,100,000
.005- .0001	Clay	10,800,000,000	11,520,000,000	14,090,000,000
	Totals	11,051,706,338	11,733,070,253	14,374,120,838

These soils are strong, as a rule, but cold and heavy, often in need of underdraining. Through cultivation, the few inches forming the soil proper become somewhat oxidized and of a brownish or dark color, from organic matter, and sharply defined from the unoxidized subsoil beneath. The total area of North America occupied by morainal soils of all kinds has been estimated by Warren Upham as upwards of 4,000,000 square miles.

The mineral nature of soils.

This part of the subject has been repeatedly touched on, but a brief summary will not be out of place here. It has been remarked already that soils consist of the least destructible minerals of the rocks. Of all the essential rock-forming minerals, quartz is the most refractory toward either physical or chemical agencies. It is for this reason that quartz forms the preponderating constituent of most sands. The feldspars undergo both a mechanical splitting up and a chemical decomposition as well; hence, a granitic soil that has undergone a moderate amount of decomposition will show feldspar fragments together with the quartz, and perhaps also shreds of mica and hornblende. Nearly all soils contain iron in the form of more or less hydrated sesquioxides. Such are largely in an amorphous, pulverulent condition, and their true mineralogical nature can be only surmised. A large percentage of any soil is made up of extremely finely comminuted and decomposed feldspars and ferruginous constituents of rocks, to which no more exact name than clay can be applied. Most rocks contain in non-essential and often microscopic amounts, a few very refractory minerals, which, as the rocks slowly rot away, accumulate in the residues in appreciable quantities. Among the minerals thus found in soils are minute tourmalines, garnets, granules of magnetic and titaniferous iron and, more rarely, zircons.

Several prominent writers have attempted to account for certain soil characteristics — as the retention of alkalies—on the ground that zeolitic minerals were formed during the process of decay. It is difficult to understand how such a conclusion could have been reached, since the zeolites do not, with a single exception, contain an essential amount of potash, and, moreover, the process of rock decay is one tending toward the breaking down and destruction of zeolitic compounds rather than to their formation. The presence of soluble potash in a soil is more logically accounted for on the supposition that, in the form of a soluble salt, it has been absorbed by the decomposing silicate minerals while in a colloidal state such as they have been shown to assume. Whatever nitrogen and carbon a virgin soil may contain came not from rock constituents but wholly from the atmosphere. The supply of silica, lime, magnesia, potash and phosphoric acid, on the other hand, is derived wholly from the rocks. The hard, bare granite ledge has locked up in its mass all the constituents needed by a plant, with the exception of those it takes from the atmosphere. It is barren only because its structure affords no foothold for plant growth. The same mass of granite, finely pulverized, will be found to contain a larger proportion of soluble plant-food than will a soil derived from it by the ordinary processes of weathering. The reason for this is that rock-weathering and soil formation are accompanied by a leaching process whereby soluble compounds are removed. This leads to the consideration of the fact first noted by Hilgard, that the soils of arid regions are richer in lime, potash and other plant-food in an available form than those of humid regions. In the formation of the one, mechanical agencies had prevailed, and the amount of material lost through the leaching action of water was reduced to the minimum. In the other, chemical decay had prevailed, soluble salts had been formed and carried away by the waters from abundant rainfalls.

Kinds and characteristics of soils.

As already noted, the ever-varying nature of soils renders an exact classification a matter of great difficulty. For the same reason, the names commonly applied to soils have no precise meaning.

The adjective terms sandy and clayey as applied, merely imply the presence of a conspicuous amount of sand or clay. A light soil is one loosely compacted and through which the water readily percolates; a heavy soil, the reverse. Sandy soils are, therefore, light, and clayey soils heavy. On the other hand, a sandy soil parts with its water more quickly than one containing an appreciable amount of clay and is, therefore, liable to be affected by drought. A clay soil parts with its water more slowly and has the unfortunate characteristic of caking on drying. A sandy soil, owing to the readiness with which it parts with its water, warms up more quickly than one of clay, and is often spoken of as a warm soil in contrast with the cold wet soil of the ground moraine. Any mellow soil is likely to be spoken of as warm, however.

A loam is a soil intermediate between sand and clay—a mixture of sand and clay in such proportions as to be lacking in the porosity of the one or tenacity and imperviousness of the other.

A marly soil is a mixture of clay and finely divided calcareous matter. A shell marl is composed largely of the shells of mollusks.

The name hard-pan is often given to the uppermost part of the subsoil which, through the downward percolation of soluble and finely divided constituents of the soil proper, has become converted into a dense, almost impervious and rock-like stratum.

An alkali soil is one containing an appreciable and often injurious amount of free sodium salts. The so-called black alkali is composed mainly of sodium carbonate, while the white alkali is a mixture of sodium carbonate and some chlorid, with at times epsom salts and borax. These constituents, with the possible exception of the last, are liberated from the silicate minerals in the ordinary processes of rock-weathering, and carried in solution down into the valleys. In regions of sufficient rainfall they are held in solution and ultimately find their way into the sea, but in arid regions and in valleys or basins with no outlet to the ocean, they often accumulate in large and injurious quantities. In short, the cause of alkaline soils is the same as the cause of the saltness of the ocean. Each is continually receiving water bearing salts in solution, which are left behind as the water is returned to the atmosphere by evaporation. That the sodium prevails over the potash in these cases may be due to the fact that alkali soils result largely from the decomposition of rocks containing soda-lime feldspars; but it is more probably due to the more complete decomposition of these feldspars rather than to their preponderance over the potash varieties. In Fig. 466 is shown an alkali field. Salt-bushes are the last attempt at vegetation.

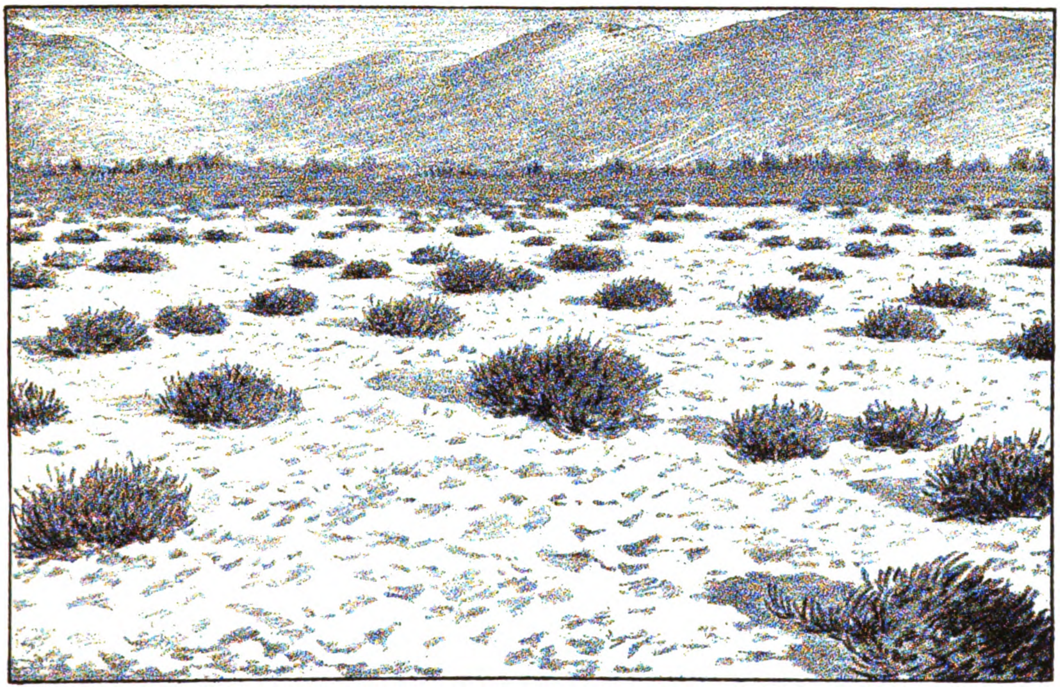

Fig. 466. The last stage of vegetation, with the accumulation of alkali, is small annual salt-bushes.

Age of soils.

The age of a soil is sometimes referred to in the literature as a matter of importance; but, while some soils are unquestionably older than others, no soil existing as such today is really old from a geological standpoint. They are among the most recent products of nature's work-shop. If the processes by which they were formed were to cease, even for a brief period, the soil, and, indeed, the entire regolith would shortly disappear under the continuous eroding activity of running water. One needs but to regard the muddy condition of the Mississippi or any of the lowland streams of the South and West, particularly after a rain, to realize how quickly this might happen were not the soil-forming process continuous. Soils have been in process of formation since the first land appeared, but the early soils, as such, have long since ceased to exist. The hard, refractory, fire-clay underlying the coal measures is thought by many authorities to represent the ancient soil on which the coal plants grew.

Rocks of all known ages have yielded to the weathering process. Among those of igneous origin the most recent do not differ, either in themselves or the character of their residual product, from the most ancient. Some authorities have thought to show that the older limestones were richer in plant-food and yielded a richer soil than those of later date, but while this may be true for a single locality, it has not yet been shown to be universally so.

The rate of soil formation.

Early writers on soils were disposed to feel that soil formation through the weathering of rocks had gone on most rapidly as well as most extensively in wooded areas and in the tropics. Later observations have tended to throw doubts on both conclusions. The forest effect is conservative, if not absolutely protective. Through affording protection from the direct rays of the sun, it prevents the extremes of temperature characteristic of other areas, and, moreover, catches and turns back to the atmosphere a very considerable proportion of the water of rainfalls, which might otherwise exert an influence. The forest prevents erosion, thereby preserving the soil and allowing it to accumulate to greater depths than might otherwise be possible, and it is probable that this has given rise to the idea that it promoted decomposition.

The relative rapidity of decomposition in hot and cold climates is perhaps still an open question. Undoubtedly, chemical agencies are most active, and for longer periods annually, in hot than in cold climates. But it must be remembered that the physical disintegration produced by frost paves the way for chemical decomposition at a vastly more rapid rate than would otherwise be possible. How far the one factor may counterbalance or outweigh the other, has not yet been shown.

Literature.

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SOILS OF THE GREAT SEMI-ARID REGION

By *T. Lyttleton Lyon*

The great semi-arid region of North America is, for the purpose of this article, conceived to include most of the states of North and South Dakota, Nebraska, Kansas, Oklahoma, western Texas, parts of Minnesota, and in Canada, Manitoba and southern Saskatchewan.

This comprises, roughly, the territory receiving an annual rainfall of 14 to 28 inches, but it is modified by the temperature and relative humidity of the atmosphere, both of which are factors in determining the supply of moisture available for plant production. The boundary of the semi-arid region east of the Rocky mountains runs much more nearly north and south than do the lines of rainfall marking the territory receiving 14 to 28 inches annual rainfall.

The lines of equal rainfall in this region bear somewhat east of a direct northerly course. For instance, Dodge City in western Kansas and Moorhead on the eastern edge of North Dakota have each a precipitation of about twenty inches annually. Central Oklahoma has nearly 30 inches of rainfall, while most of Minnesota and a part of Iowa do not have more than that amount. It is evident, when the agricultural conditions of these regions are compared, that some factors other than the amount of rainfall determine the available moisture supply. Of the other factors, temperature and relative humidity are the most potent, as these largely determine the rate of moisture evaporation. The mean temperature for the crop-growing season naturally decreases from south to north, but not nearly so rapidly as the mean for the entire year. The fact that it is cooler in the northern part of the region, especially at night, serves to diminish evaporation that occurs in the course of twenty-four hours.

The average relative humidity at Dodge City, Kansas, for July is 62 per cent. At Bismarck, North Dakota, almost directly north, it is 65.3 per cent. The greater dryness of the air in the southern part of the semi-arid region, therefore, increases the rate at which moisture is taken from the soil under otherwise similar conditions. It also results in a somewhat greater number of cloudy days for the northern section, and prevents the soil from absorbing as much of the heat of the sun.

Another factor affecting evaporation is the wind. The velocity of the wind is generally somewhat greater in the southern than in the northern part of the semi-arid region east of the Rocky mountains. For instance, at Dodge City, Kansas, the mean velocity in July is twelve miles per hour, and at Bismarck, North Dakota, it is nine and a half miles per hour in the same month. Another feature of the wind movement is the fact that the prevailing wind in Oklahoma, Kansas and Nebraska, in the crop-growing season, is from the south. In the Dakotas and Canada it is more likely to blow from the north.

One of the characteristics of the semi-arid region is the great rate of evaporation as compared with the amount of rainfall. For purposes of comparison, evaporation is best determined by measuring the daily loss from a free water surface. The total loss for the year in this region always exceeds the annual rainfall. From north to south the rate of evaporation increases rapidly. For instance, the total annual evaporation from a free water surface at Amarillo, Texas, is 55.4 inches; at North Platte, Nebraska, 41.3 inches; at Dodge City, Kansas, 54.6 inches; at Bismarck, North Dakota, 31 inches; at St. Vincent, North Dakota, 22.1 inches. These places all have an annual rainfall of about eighteen to twenty inches.

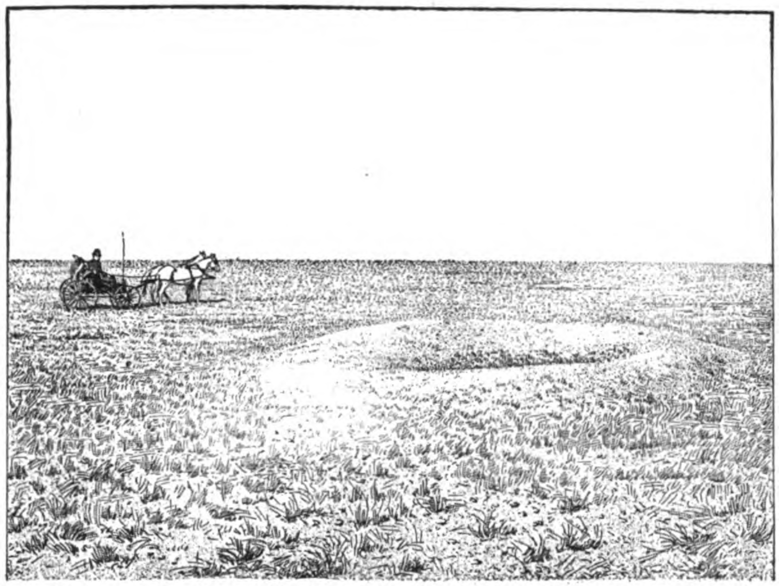

Fig. 467. Unbroken prairie of loess soil composed largely of silt particles, and 300 feet in depth. The native grasses are sod-formers on such land. When tilled, it is well-adapted to small grain and grasses if it receives sufficient moisture. (Page 344.)

Under otherwise similar conditions the loss of moisture from the soil by evaporation is considerably greater in the southern than it is in the northern part of the semi-arid region, and the lines of equal rates of evaporation would have a bearing to the west as they proceed northward.

Evaporation, as well as rainfall, exercises an influence on crop production, the amount of the former increasing from east to west, while that of the latter augments as it proceeds eastward. At two points, one directly north of the other, the effect of diminished rainfall is compensated for by lessened evaporation, so that, other things being equal, similar crops do equally well. The eastern boundary of the semi-arid region, east of the Rocky mountains, may be considered, therefore, as extending almost directly north and south.

Soil areas.

Within the semi-arid region are several large areas, the soils of which differ from each other in the methods through which they have been formed or transported. While it can not be said that all of the soil within any one of these areas is of the same origin, it is true that a large part of it is similar in that respect, and this gives it more or less uniformity as viewed from the standpoint of the agriculturist. It indicates a certain degree of fertility pertaining to the area as a whole, but the distribution of the various constituents determines local productiveness.

There are also places in which occur what have been called "belted soils," caused by the erosion of a prevailing surface soil and the exposure successively of one or more underlying strata. Thus, there may be exposed in the loess area drift and Pierre shale, or in the sand-hill area high plains soil and Pierre shale. Soils so exposed will evidently not conform to the characteristics of that of the area in which they occur. They merely constitute exceptions to the type of prevailing soil.

The soil areas found in the semi-arid regions may be designated as follows:

Glacial drift formation.
Pierre shale formation.
Loess formation.
Sand-hill formation.
High plains soil formation.
Red beds formation.

To these might be added the "Bad Land" soil, were that region of more agricultural importance. These areas are rather well defined and, in general, each lies in one continuous body; but in the case of the sand-hill and loess formations detached areas of one sometimes occur in the midst of the other.

Glacial drift.—The soil of Manitoba, Saskatchewan, western Minnesota, and the eastern part of North Dakota and South Dakota is largely of glacial origin, and parts of this, notably the soil of the Red river valley, are composed of the glacial mud that has been deposited in the bottom of lakes formed after the glaciers, which once covered the northern states and Canada, had withdrawn to the northward. The soil has the structure characteristic of soils of glacial origin, in that particles of all sizes occur, varying from the finest clay to enormous boulders. In a large part of the region this soil material is indiscriminately mixed, but in the region contiguous to the Red river and forming the bed of the ancient Lake Agassiz, the water has sorted the material with some reference to the size of the particles.

During the process of thawing the ice gorge, the waters of the lake stood at various levels, which are now marked by sand and gravel beaches, the finer particles having been carried out into the lake and deposited in deeper water. The part of the lake bottom receiving this fine soil is very level and in some places poorly drained. Alkali spots occur to some extent, and gumbo is present.

The soil of the glacial drift area is well supplied with all the elements of fertility, notably humus and lime. Most of the analyses of these soils show more than 1 per cent of lime, and very few less than a half per cent. The content of humus in the surface soil of the Red river valley runs from 2 to 5 per cent, but is lower in the western part of the area as the more stony parts of the formation are reached, and decreases rapidly under the system of continuous wheat cropping and summer fallow that is practiced in that region. The large amount of these two constituents, together with a sufficient quantity of the other elements of plant-food, results in the ready availability of fertilizing material, which has made it possible, without artificial fertilization, to secure remarkable yields of wheat.

Potash is found in liberal quantities and phosphoric acid generally in fair amount, but in some localities this latter is so low as to indicate a probable deficiency in this constituent, should the content of humus be allowed to become low.

Pierre shale.—Large areas of central South Dakota and a small part of northeastern Nebraska are covered with a surface soil derived from Pierre shale. The formation consists almost entirely of dark gray clay and is rather uniform in its character. The heavy tenacious character of the soil adapts it to the growth of grass, but makes it difficult to till. It generally has the structure and properties of gumbo. When dry it is extremely difficult to plow. If worked when wet, it forms large clods on drying. To secure good tilth it is necessary to work it during the brief period when it is neither too wet nor too dry. Fortunately, most of this soil is found in a region devoted to grazing. It produces abundant pasturage of the sod-forming grasses. However, on land of this character good water is likely to be scarce, and wells must be sunk very deep in order to secure a sufficient supply.

Physically, the soil is composed very largely of clay particles, with a small amount of silt and fine sand. It has the properties of a heavy soil.

Chemically, it is a rich soil, but it contains enough soluble salts to produce gumbo in many places, which, unless corrected, greatly reduces its productiveness. It is greatly benefited by the use of barnyard manure.

Loess soil.—In eastern Nebraska and northeastern Kansas are large areas of loess soil having a characteristic structure and appearance, and corresponding to the glacial mud of Minnesota and the Dakotas in its fertility. It occurs generally as rolling prairie, and in places is of great depth. Fig. 467. The surface and subsoil differ

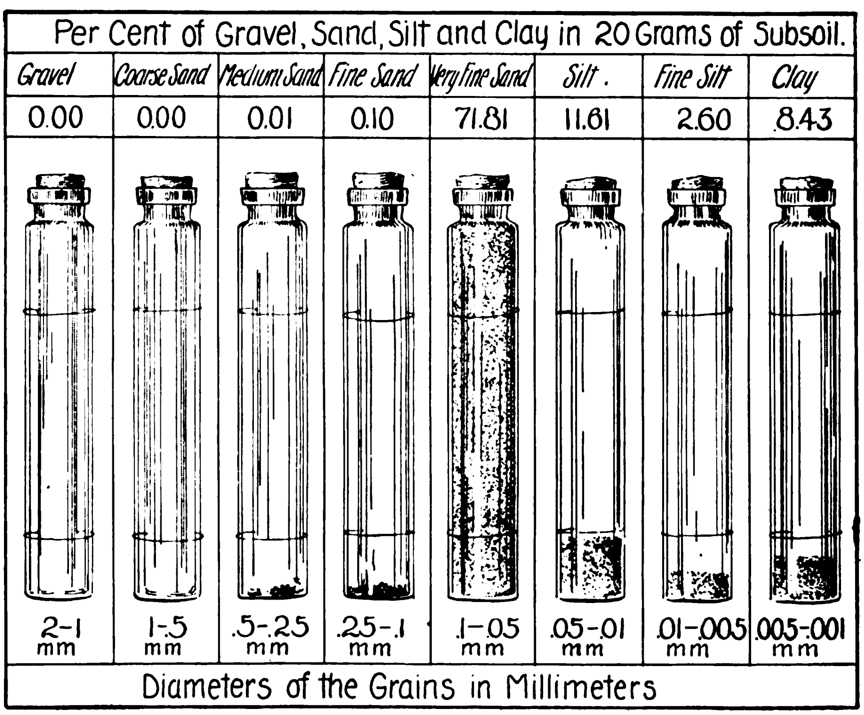

Fig. 468. The texture of a typical subsoil of the high plains formation in Cheyenne county, Kansas.

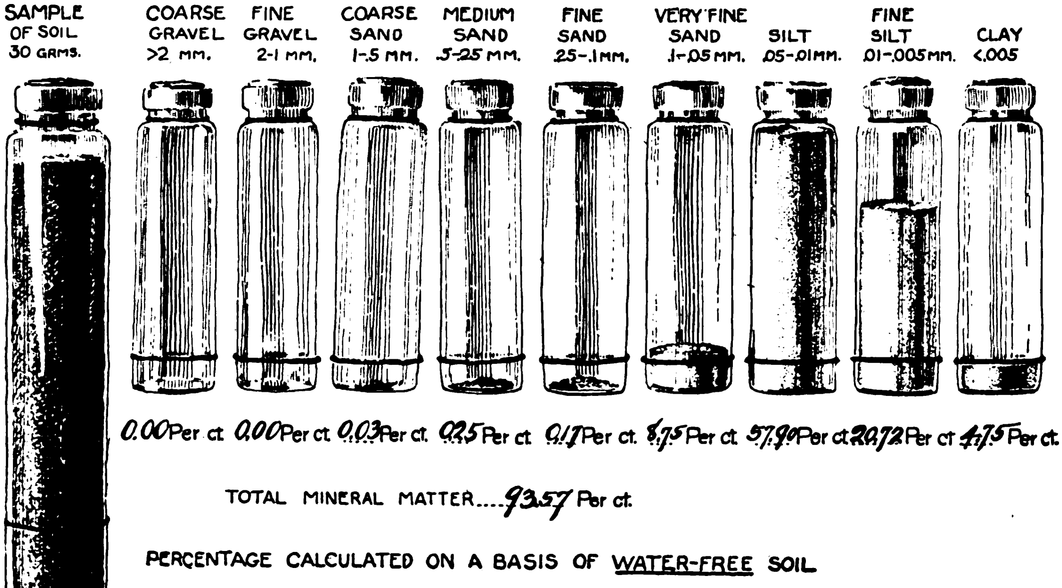

Fig. 469. Mechanical analysis of loess soil from York county, Nebraska.

little in their structure and composition, aside from the fact that there is a gradual decrease in the percentage of organic matter as the depth increases. Loess soil is probably the product of glacial action and has been transported to its present location, either by wind or water, or possibly by both. In localities where loess has been washed away drift soil is exposed.

The readily available fertility of the loess subsoil is of great importance in crop production, especially for the deep-rooted plants, as alfalfa. This peculiarity of the subsoil is common to other soils in the arid and semi-arid regions and is, doubtless, one of the potent reasons for the success which attends the culture of alfalfa throughout a large part of that territory.

The typical loess soil of Kansas and Nebraska is in structure a light-textured loam with a large proportion of silt, considerable very fine sand, and a relatively small proportion of clay and coarser sand. Figs. 468 and 469 show mechanical analyses of typical high plains and loess soils respectively. The loess is remarkable for its uniformity of structure throughout the region, but it becomes more sandy toward its western limit. The proportion of humus is usually high, giving the soil a dark brown color, sometimes almost black. The percentage of humus decreases as the region becomes drier and, consequently, the soil becomes correspondingly lighter in color. This soil has wonderful ability to form humus from plant tissue. Excavated subsoil will immediately support vegetation and in a short time begin to assume a brown color, so that in two or three years there will be several inches of the dark brown surface soil. The strong humus-forming tendency is probably due to its easy permeability to air, and the presence of soluble salts of alkalies and alkali earths which occur abundantly.

The same salts are also, doubtless, the cause of another singular and characteristic feature of the loess soil. Vertical tubes, lined generally with a more or less white coating of mineral matter, are found very commonly in undisturbed loess soil. The coating is somewhat easily soluble and has probably been deposited in its present form by water percolating downward, or drawn upward. When the soil is of great depth and the rainfall is small, there is no loss of moisture by percolation in much of the semi-arid region. The large mass of soil absorbs all of the rainfall and delivers it again to the atmosphere by evaporation. The upward movement is due to capillarity, the downward to capillarity and gravity. The soluble salts are thus removed from the soil only by lateral seepage, which carries much of them into lower levels and there produces "alkali spots." The remainder are carried upward and downward with the percolating water. As the descending water reaches the lower levels of the soil, the salt solution becomes more concentrated, and at last there is deposition. The water drawn upward by surface evaporation likewise becomes concentrated as the supply becomes exhausted, and as the salts are deposited they form the lining of the openings through which the moisture is rising.

Chemically, the loess is a rich soil. The humus content is high in regions of good rainfall, but decreases with more arid conditions. Lime is present in sufficient quantity and in the proper combinations to make the other plant-food most effective. Potash occurs in large amounts, and phosphoric acid is generally present in sufficient quantity. The loess soil is particularly well adapted to raising corn, and, as the climate in which most of it lies is also suited to that crop, the result is an enormous production of corn from the loess area. The western part of the loess area constitutes an important part of the hard winter wheat territory. A winter wheat, similar in its bread-making qualities to the northern spring wheat, is produced on this soil in Kansas and Nebraska. While the soil is somewhat light in texture for wheat, yet it produces, under good management, yields of thirty to forty bushels per acre.

Most of the wheat is produced in the area where the rainfall is too light to insure good yields of corn. Wheat has the advantage of maturing early in the summer, and thus is not exposed to the hottest part of the season, and makes most of its growth in the months of greatest rainfall, which in this region are May and June. It can, therefore, make a crop in a drier region than can corn.

Fig. 470. Characteristic loess bluff, produced by erosion. Height 60 feet.

Sand-hill area.—In western Nebraska is a vast area of sandy soil that has been drifted into low irregular hills, now generally covered with grass, but still likely to drift when unprotected by this covering. (Fig. 471.) Detached areas of these sand-hills are also found in western Kansas and southward. The sand-hills are derived from the sandy tertiary formations. In texture the soil is very light, being composed largely of fine and very fine sand, with silt next in amount, and smaller proportions of the coarser sands and clay. Rains have carried a considerable amount of small particles into the depressions, or "pockets" as they are locally termed, between the hills, so that the soil there is heavier than elsewhere. The "pockets" are frequently without surface drainage, showing the newness of the hills and the light rainfall of the region. Table water usually stands within a few feet of the surface of the depressions.

The soil is not of lasting productiveness and, with the exception of some of the low lands, will never be adapted to general farming. The accumulation of heavier soil and humus on the low ground fits it for the production of hay, particularly alfalfa, and to some extent for other crops. On the uplands, bunch grasses grow and furnish pasturage, but this is so scant that at least ten acres of land are required for every head of cattle. There is very little humus in the high soil. Forest trees, especially conifers, can be raised successfully on the sand-hills, and this region will doubtless produce a large amount of lumber at some future time, although now it possesses almost no timber.

High plains soil.—Another phase of tertiary material is what may be called the high plains soil, found in extreme western Nebraska, and in most of the western third of Kansas, western Oklahoma and extreme northern Texas. The region is one of the great stretches of level plains, covered with a thick sod of short, curly buffalo and grama grasses, and broken in the neighborhood of the streams that traverse the region, by steep cañons leading into the valleys. When the cañons do not occur the entire rainfall is absorbed by the soil, and there is no erosion of the sod-protected soil.

The altitude of the high plains varies from 2,500 to over 5,000 feet. The climate is healthful, and the soil is of good quality. Wells of the upland afford a splendid quality of water at depths ranging from 50 to 300 feet. It is a region that has attracted settlers for many years and at times parts of it have been thickly settled. Towns of considerable size have been built and have disappeared. These occasional incursions of settlers have generally been coincident with a series of years of good rainfall, for this region is peculiarly liable to periods of heavy and periods of light precipitation, each lasting for several years. As the soil is good, and especially as it contains soluble plant-food, by reason of the fact that it is not subject to leaching, remarkably large crops can be raised in years of abundant rainfall. Any one visiting the region at such a time is likely to be impressed with its productiveness, and the result has been that large immigrations have several times occurred, and each time most of the settlers have abandoned their farms and left the country after encountering a period of small rainfall. Some, however, have remained, and these are gradually working out the problem of "dry land farming."

In texture, the soil is a light loam in which very fine sand predominates, with silt particles next in amount. The proportion of clay is low. There is considerable fine sand, with a decreasing amount of larger particles and some gravel.

It is well provided with the essential elements of fertility and, considering the light rainfall of the region, has a good supply of humus, which it has derived from its thick growth of grasses. Its lime content is rather high, as is also the potash, but phosphoric acid is low.

While it is not a soil of such lasting fertility as the loess, its plant-food is in readily available form, and the seasons of good rainfall always find it ready to produce a crop. Winter wheat, durum wheat, Kafir corn, and sorghum are being profitably produced on this soil in a region of very light precipitation.

Red beds soil.—South of the high plains area and extending through central Oklahoma and northern Texas, lies the red beds soil. In Oklahoma these lands receive a fair amount of rainfall, but as they pass through Texas the climate becomes more arid and plant growth more difficult. The area thus includes a farming region and a grazing country. The soil is, in the main, rather heavy in texture and is well adapted to small grain, particularly wheat. Silt and clay particles make up the bulk of the soil, but in some localities it becomes sandy. The soil has a characteristic red color, which it imparts to the streams that traverse the region. There is a fair amount of all the necessary constituents for the production of good crops on this soil, with the exception of humus, of which there is not a sufficient amount in soil that has been under cultivation for a long time. One of the greatest problems in the management of this soil is the maintenance of the humus content.

Soil management.

Although there are great differences between soils in the semi-arid regions, there are certain characteristics that are very common, and certain operations that are essential to secure the best results. It has taken a long time to learn the methods of soil management best adapted to the region, and their adoption is a still more difficult task. The present generation of farmers is the first that has tilled the soil of the semi-arid region. They and their ancestors came from a humid region. Their experience and their traditions are derived from conditions essentially different from those which they now face. It is not strange that they should be slow to adapt themselves to the requirements of a dry climate.

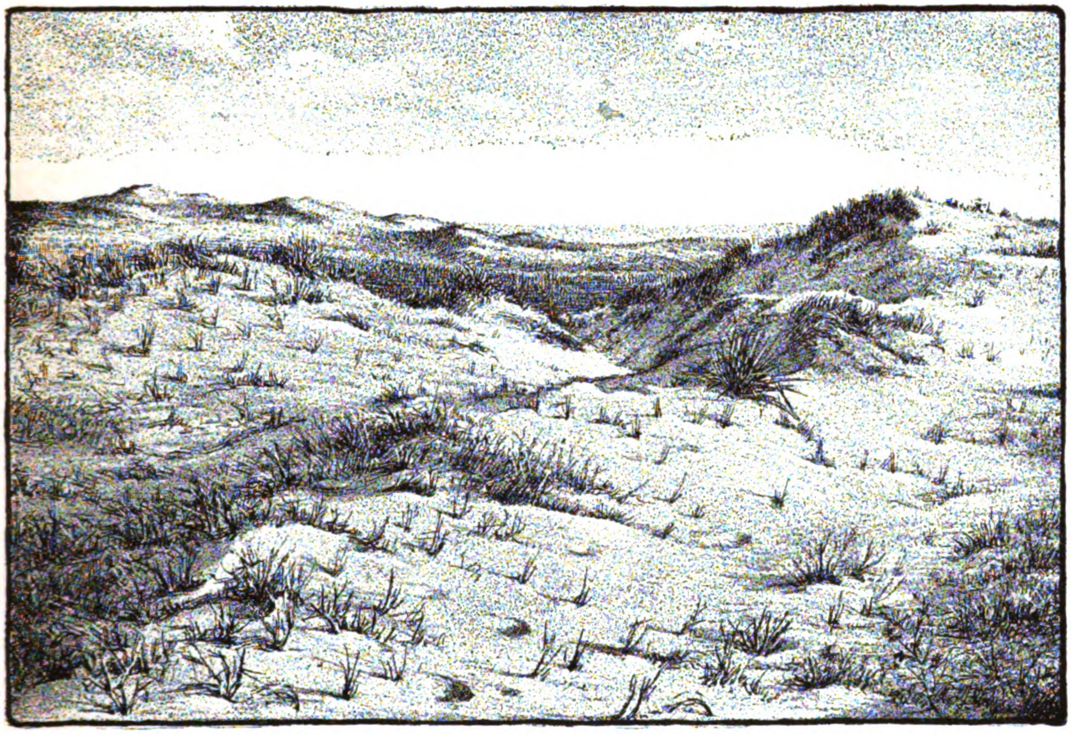

Fig. 471. Sand-hills that have not entirely ceased to drift. As the grass becomes better established the sand will be held in place.

Maintenance of humus.—Year after year of prairie grasses has filled the soil with humus, a fortunate thing for the farmers, for without this large amount of humus the soil is poorly adapted to withstand the long periods of drought that sometimes occur. As it is, the water-holding power of the soil is remarkable and enables crops to withstand periods of drought that would be disastrous in some regions.

When new soil is subjected to tillage, the humus at once begins to decrease in amount. Aëration is naturally very thorough in these soils, and when aided by plowing it results in rapid decomposition of organic matter. One-half of the humus in a soil has been lost in a few years after the sod was broken.

It is evident that the conditions that produced the humus will restore it. Seeding to grass, clover or alfalfa has a wonderful effect in improving the water-holding power of the soil. Seeding down is, however, little practiced because of the difficulty in getting the crop started in much of the semi-arid region, and a disinclination on the part of farmers to plow up such a valuable crop.

Another useful feature of the humus is its property of making plant-food more readily available to the plant. A drift or loess soil, when new, will frequently contain, in combination with organic matter, 800 pounds of potash and 1,200 pounds of phosphoric acid in an acre of soil one foot deep. A similar soil under continuous cultivation for a few years, will frequently contain only half as much.

The use of barnyard manure will also serve to form humus, but in the wheat-raising sections relatively few cattle are kept, and in the corn-growing section the cattle are usually fed in yards from which the manure is not easily collected. Thus it is that little manure is applied to the land.

Tillage in general.—Tillage in the semi-arid region presents some phases that are essentially different from those in the humid section of the country. The properties of the soil which allow of such abundant aëration make it desirable to pay fully as much attention to compacting the soil as to stirring it. Otherwise, the large openings in the soil allow it to dry out rapidly.

Plowing must frequently be done when the soil is rather dry, and under such circumstances it is very likely to turn over in large clods which leave wide spaces between, a condition admitting of rapid drying. There are two ways in which a more compact condition of the plowed land may be secured. (1) By disking before plowing, thus fining the soil to be turned under, which results in fewer clods and in filling the spaces with soil. (2) By compacting the lower soil after it has been plowed. This is done by following in the direction of the plowing with a disc harrow, having its discs set straight for the purpose of breaking down clods and compacting soil near the bottom of the furrow. An implement called a subsurface packer, made especially for the purpose, is more effective than the disc. The subsurface packer was invented by Mr. H. W. Campbell, who has advanced many other good ideas in regard to soil tillage in the semi-arid region, and who is the author of "Campbell's Soil Culture Manual." [For an article by Mr. Campbell, see Chap. XI.] The subsurface packer consists of a number of wheels about 18 inches in diameter set on an axle. The rims of the wheels are wedge shape, and as they pass through the soil they break down lumps and firm the lower soil. To get the best results, these methods should be combined, and the land first disked and afterward packed. It is also very desirable that the harrow follow the plow after each half-day's plowing. Clods dry out so rapidly in this region of large evaporation that delay in harrowing is likely to make them very difficult to break.

Deep plowing is generally desirable unless the crop is to be put in soon after the plowing is done, in which case the soil may be too loose if plowed deep, especially if not disked and packed. On the other hand, land should not be plowed shortly before seeding, but several weeks or months before, and in the intervening time the surface of the soil should be kept loose to prevent evaporation of moisture. In this way the seed-bed becomes well settled, establishing an upward movement of moisture from the lower soil. Fall plowing is generally advisable, but certain soils become too loose by spring when fall plowed, and some drift so badly with the wind that they require the protection afforded by standing vegetation of some kind. Soil-drifting is one of the serious problems in sections of the semi-arid region. Occasionally a field ready for the seed or already planted will have the entire surface soil, to the depth of several inches, completely swept away by the wind. Light-textured soils and those deficient in humus suffer most in this way.

Subsoiling, with a plow designed to loosen the soil beneath the furrow-slice but not to bring it to the surface, has been tried in many places with a view to increasing the water-holding capacity of the lower soil. On land with a heavy clay subsoil, this practice has been beneficial, but on the light subsoil, characteristic of much of the semi-arid region, it has not been productive of good.

Frequently land is prepared for a crop by merely disking it or by cultivating in the seed of small grain. Of these two methods, disking and seeding with a drill is doubtless preferable. Land that has been planted to a cultivated crop, such as corn, forms under such treatment an excellent seed-bed for small grain, and, when the trash is removed, a good bed for alfalfa or grass seed. The previous cultivation, if it has been thorough, has left the surface soil in good tilth and has stored it with a readily available fertility. The natural aëration of the soil, aided by the previous cultivation, is sufficient without the operation of plowing.

What practically amounts to tillage, on much land, is the practice of listing corn. Listing and inter-tilling is all the tillage that much of the corn land ever gets, for it is planted to listed corn year after year without plowing. Listing consists in opening a furrow several inches deep by means of an implement with a double moldboard, and depositing the seed corn about two inches beneath the bottom of the furrow. The advantages of the practice are that the roots of the corn are deeper than those of surface-planted corn and, therefore, suffer less from drought and heavy wind. The disadvantage is that the soil is not plowed. It requires a soil of easy permeability to air to yield good crops year after year with this treatment. On much of the soil of the semi-arid region, listing produces better yields than plowing and surface planting. An implement for listing on plowed ground has been put on the market, the use of which, on many soils, should combine the good points of both methods of planting.

Cultivation.—The great object of cultivation in the semi-arid region is to retain moisture. By breaking up the compact condition of the surface soil, the capillary rise of water to the surface is in large measure prevented. The loss of moisture, avoided by a loosened layer of soil three or four

Plate XIX **Plowing for wheat on a bonanza farm, Amenia, North Dakota.** This is "the postage stamp picture," being the original of a two-cent stamp made for the Omaha Exposition. The teams at work on various parts of these great farms are often brought together at one place to be photographed inches thick, is equivalent to several inches of rainfall in the course of a season.

Whenever the land does not carry a crop and whenever a crop admits of tillage, it is desirable to keep the surface soil stirred. The slant-tooth harrow and the weeder are both excellent for cultivating corn and small grain when they are young. These implements cover a large extent of ground in a day and leave the surface of the soil well-stirred. If the soil be hard, the weeder is not so effective as the harrow. Inter-tilling small grain is a practice peculiar to the semi-arid region. When the crop is drilled in rows six to eight inches apart, harrowing in the direction of the drill rows after the grain is up and well started on its growth, is an excellent way to retain moisture and increase the yield. Tillage of crops planted farther apart is of proportional importance. Experiments in the region where the annual evaporation reaches forty inches have shown that the soil should be stirred three to four inches deep to prevent evaporation most successfully, but that a greater depth is not desirable.

Fallowing land.—Fallowing land is a common practice in the semi-arid region. This consists usually in plowing the land and then leaving it without a crop for a year or a part thereof. Usually the surface soil is kept stirred more or less during the time it lies fallow. The object of the practice is to allow moisture to accumulate in the soil for the next year's crop and to store up available plant-food. So far as this operation serves to retain moisture, it is beneficial, but in decomposing humus and rendering nitrogen available it is very wasteful. Snyder has shown that for every pound of nitrogen converted into nitrates four pounds are lost to the soil. Fallowing land every other year, as is often done, is for this reason inadvisable, but keeping the surface of the soil stirred during such periods as may occur between crops, is a good practice. After a crop of small grain has been removed, the soil should be immediately disked and kept loosened on top until another crop is put in.

Future of the semi-arid region.

There can be no doubt that the semi-arid region is destined to be of great agricultural importance. Certain parts will be more productive than others, notably drift, loess and red beds soils. Productiveness will always depend on the humus content of the soil, and the heavier soils will lead in that respect. The study and practice of the best methods of soil tillage and of crops adapted to a dry climate has already done much to put farming on a more certain basis, and will do much more in the future. The second generation will be in a better position to meet the conditions of semi-aridity than was the first, and to them we must look for the complete conquest of the great semi-arid country.

Literature.

The reader is referred to the following publications for further information: United States Geological Survey, Professional Paper No. 32, "Preliminary Report on the Geology and Underground Water Resources of the Central Great Plains." United States Department of Agriculture, Bureau of Soils, Annual Reports 1902, 1903. Minnesota Experiment Station Bulletins, Nos. 30, 41, 53. North Dakota Experiment Station Bulletins, Nos. 24, 29, 32, 35, 36, 38, 47. South Dakota Experiment Station Bulletin, No. 79. Nebraska Experiment Station Bulletin, No. 54. Oklahoma Experiment Station Bulletins, Nos. 5, 42, 50. Texas Experiment Station Bulletins, Nos. 25, 61, 67. University Geological Survey of Kansas, Vol. 2. Nebraska Geological Survey, Vol. 1. United States Geological Survey, Part 4 of 21st and 22nd Annual Reports, "Reclamation of the High Plains." United States Department of Agriculture, Weather Bureau, Climate and Crop Service Reports for North Dakota, South Dakota, Nebraska, Kansas, Oklahoma and Texas.

THE PHYSICAL PROPERTIES OF SOILS

By *W. H. Stevenson*

The physical characteristics of a soil largely determine its agricultural value. This is true because the physical properties, such as its texture and color, determine in a very large measure the temperature and moisture conditions, and the amount of air within the soil. The productive capacity depends quite as much on these factors as on its chemical composition, for the reason that temperature, moisture and ventilation greatly affect the growth of crops.

The physical characteristics of a soil depend for the most part on its natural character. Certain methods of soil treatment may modify these characteristics to a limited extent, but in the main a coarse gravelly soil or a heavy clay remain such under practically all methods of soil management. For this reason it is essential that care be exercised in the selection of a farm or field to secure a soil possessing the right physical characteristics for any particular crop. Certain crops seem to be best adapted to particular kinds of soils because of the peculiarities of the crop with reference to its demands for definite amounts of water and certain temperatures. Thus, wheat seems to thrive on land with a clay subsoil, potatoes in a sandy soil, and corn in a silt soil.

However, so many factors influence plant growth that a knowledge of the physical nature of a soil will not, in itself, afford complete data regarding its crop-producing power. For example, a coarse-grained soil, such as a sandy soil, in which the water table is within a few feet of the surface, may produce larger grain crops than a clay soil in which the water stands much deeper. Again, the physical nature of a soil may be changed by cropping to such an extent that a soil that was formerly loose and mellow is rendered too compact and retentive, and for this reason yields inferior crops. A partially puddled or cloddy condition is unfavorable to plant growth; hence, every effort should be put forth to maintain all cultivated soils in a mellow and crumbly condition. It is evident that there is an intimate relation between the physical characteristics of a soil and successful crop production.

The following are counted the more important physical characteristics of soils: (1) Weight and specific gravity. (2) Texture. (3) Color. (4) Relation of the soil to water. (5) Relation of the soil to heat. (6) Relation of the soil to air. (7) Odor and taste.

Weight.

Soils vary widely in weight according to their composition and the size of the particles. Humus soils are the lightest and sandy soils are the heaviest; between these extremes there is every possible variation. Clay soils weigh less per cubic foot than arable soils or sandy soils. The larger the amount of organic matter in a cubic foot of soil, the less it weighs. For this reason surface soils are lighter, as a rule, than subsoils.

The weight of dry soil in a given depth per acre is determined by removing definite volumes of soil, drying and weighing them. The weight of a cubic foot of dry soil is given by Shubler as follows:

Silicious sand	110	pounds
Half sand and half clay	96	"
Common arable soil	80 to 90	"
Heavy clay	75	"
Garden mold rich in vegetable matter	70	"
Peat soil	30 to 50	"

Warington gives the following data regarding the weight of soil per acre:

1. Old Pasture, Rothamsted, Loam with Clay Subsoil.

	Original wet soil	Dry soil			
		Total	Stones	Fine soil	Roots
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
First 9 inches	3,294,380	2,328,973	174,091	2,144,470	10,412
Second 9 inches	3,867,780	3,098,939	353,322	2,744,715	902
Third 9 inches	4,091,620	3,273,324	217,515	3,055,501	308
Fourth 9 inches	4,139,420	3,343,787	280,730	3,063,057	

2. Arable Land, Rothamsted, Loam with Clay Subsoil.

	Original wet soil	Dry soil			
		Total	Stones	Fine soil	Roots
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
First 9 inches	3,288,553	2,919,689	340,656	2,578,634	399
Second 9 inches	3,688,115	3,044,615	141,861	2,902,682	72
Third 9 inches	3,882,285	3,215,285	213,190	3,002,095	
Fourth 9 inches	3,995,723	3,313,563	197,400	3,116,163	

3. Arable Land, Woburn, Sandy Soil.

	Original wet soil	Dry soil			
		Total	Stones	Fine soil	Roots
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
First 9 inches	3,835,104	3,157,448	93,763	3,063,074	611
Second 9 inches	3,947,640	3,381,804	201,527	3,180,277	
Third 9 inches	4,046,364	3,462,498	170,443	3,292,055	
Fourth 9 inches	4,014,432	3,501,466	274,239	3,227,227	

These tables show: (1) That each of these classes of soil is lighter at the surface; (2) that in each case the weight increases with an increase in depth. This increase in weight of the lower zones is due: (1) To the increase of pressure to which the lower zones are subjected; (2) to the fact that the surface soil is more loose and porous. This condition is brought about by the removal of the finest soil particles from the surface into the subsoil by the action of rain; by the accumulation of organic matter in the surface soil; and, in the case of arable soils, by tillage.

The specific gravity of a soil indicates its weight as compared with the weight of an equal volume of water. An English authority has published the following table, which gives the specific gravity of the more common soil constituents:

Water	1.00	Dolomite	2.8–3.0
Humus	1.2 –1.5	Mica	2.8–3.2
Clay	2.50	Hornblende	2.9–3.4
Quartz	2.62	Augite	3.2–3.5
Feldspar	2.5 –2.8	Limonite	3.4–4.0
Talc	2.6 –2.7	Hematite	5.1–5.2
Calcite	2.75		

Schöne gives the following for the specific gravity of different soils:

Clay soil	2.65
Sandy soil	2.67
Fine soil	2.71
Humus soil	2.53

The true specific gravity of an arable soil varies from about 2.5 to 2.7.

A soil is not a solid mass, but is composed of particles that touch each other only at certain points. Usually about 50 per cent of a given volume of soil is air space. Hence, a cubic foot of dry soil does not weigh so much as we might assume from the specific gravity of its constituents. Because of the fact that only a part of a cubic foot of soil is occupied by solid material, we have both a real and an apparent specific gravity. The "apparent specific gravity" of a soil is determined by dividing the weight of a given volume of dry soil by the weight of an equal volume of water.

According to Wollny, the apparent specific gravity of powdered air-dried quartz is 1.449; of clay, 1.011; of humus, 0.335. When the apparent specific gravity of a cubic foot of soil is known, the weight can be determined by multiplying by 62.42, which is the weight in pounds of a cubic foot of water. An ordinary arable soil in good tilth has an apparent specific gravity of about 1.2, and therefore weighs 74.9 pounds per cubic foot.

Sand is the heaviest of soil constituents; clay is lighter; humus is the lightest. Therefore, when we find that the specific gravity of a soil is low, we have good evidence that the soil is rich in humus.

Texture.

The texture of a soil is determined by the size and shape of the particles of which it is composed and the manner in which these particles are grouped in kernels or crumbs, which give it its composite granular structure. The texture of a soil determines in a large measure its physical properties and its agricultural value. Too great compactness and too open structure are undesirable. When a soil is puddled it is in a condition which renders it practically impervious to water and air. Its granular structure has been broken down and the separate soil grains are brought into the closest possible contact. A puddled soil is not in a favorable physical condition for the production of crops, because the movement of air and water is too slow to afford suitable drainage and ventilation. Clay puddles readily.

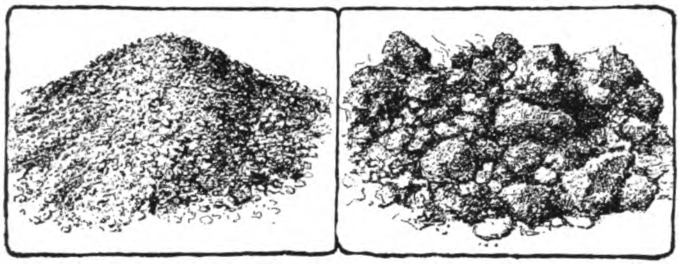

Fig. 472. Showing the great differences in texture of soils. The finer soil offers many times more surface to the action of air and of solvents. It will also hold more moisture.

Too open structure or texture, such as is found in coarse sandy soils, is undesirable because it permits the water from rains to pass downward with too much rapidity; an open structure also permits the too rapid oxidation of organic matter. In short, a soil should be sufficiently compact to prevent excessive leaching and should possess a texture sufficiently open to afford adequate drainage through percolation, and also requisite ventilation.

The size of soil particles sustains an intimate relation to the total amount of surface exposed to the action of air and of solvents. The finer the particles the greater is the total surface. Hence, the total surface in a cubic foot of fine clay soil is much greater than in coarse sands and gravels. Hall says: "As a rough figure to remember, the surface of the particles in one cubic foot of an ordinary light loam may be taken as about an acre; this will increase as the soil approaches more and more to clay, and diminish as the soil becomes increasingly sandy."

The extent of surface exposed by the soil particles is an important factor in plant growth, for the following reasons:

(1) The amount of plant-food made available in the soil depends almost directly on the extent of surface exposed to the action of air and water and to the acids that are given off by roots. The productiveness of a soil, with few exceptions, is in proportion to the amount of the soluble constituents. Hence, other things being equal, the finer the soil the more productive it will be, except in the case of excessive fineness. A soil with this latter characteristic may hold water so tenaciously as to render it too wet for profitable crop production.

(2) The water in the soil is in the form of a film that surrounds the individual soil particles. Hence the amount of water which a soil can hold, as a rule, is in proportion to the amount of surface of all the particles.

The size and form of the particles determine the number in a given volume of soil. It has been estimated by Whitney that a gram of soil contains 2,000,000,000 to 20,000,000,000 soil particles. This authority states that the number of particles per gram of different soil types is approximately as follows:

Early truck	1,955,000,000
Truck and small fruit	3,955,000,000
Tobacco	6,786,000,000
Wheat	10,228,000,000
Grass and wheat	14,735,000,000
Limestone	19,638,000,000

Owing to the fact that a soil is made up of particles, there is between them a certain amount of space that is occupied by air or water; this is known as the "pore space." In ordinary soils the pore space varies from a little over 50 per cent in the finest clay soils to about 25 or 30 per cent in coarse sands of uniform texture. The finer-grained soils possess the greater pore space because the light particles do not overcome friction sufficiently to pack into the arrangement, giving the minimum pore space.

A soil in the field generally possesses a larger pore space than the shape and size of the particles would indicate. This is true because the stirring due to cultivation and the presence of humus make definite holes or cavities in the soil. The pore space of a soil sustains an important relation to its water-holding capacity. The pore space determines the number of inches of water which a soil will store away before allowing the falling water to flow away over the surface or percolate downward in the drainage water.

Mechanical analysis. (See also pp. 366–369.)—Owing to the fact that the physical properties of a soil are largely dependent on the size of the particles of which it is composed, it is often important to know the proportion of particles of different sizes. This data can be secured most accurately by means of a mechanical analysis. In such an analysis the particles which make up a soil are grouped by placing all that lie between two dimensions in one category. The names given to these various groups are rather indefinite and vary according to the scheme of analysis. The following classification of soil constituents has been adopted by the Bureau of Soils of the United States

Department of Agriculture and by many investigators:

Name	Size of particles
1. Gravel	2 to 1 mm.
2. Coarse sand	1 to .5 mm.
3. Medium sand	.5 to .25 mm.
4. Fine sand	.25 to .1 mm.
5. Very find sand	.1 to .05 mm.
6. Silt	.05 to .005 mm.
7. Clay	.005 to .0001 mm.

Particles of one size or grade predominate in most soils, as clay in heavy clay soils and medium sand in sandy soils. When the fragments of rock are so coarse that very few of them are smaller than 1 mm. in diameter, we have a coarse sand rather than an agricultural soil. It is of interest to note that no soil is composed of particles of only one grade.

A mechanical analysis conveys valuable information concerning the physical character of a soil. Soils with a very high percentage of total sands are loose and open and possess in large measure the characteristics of sand; those with less sand are not so open and loose, are better adapted to crop production, and are classed as loams. Soils with a high percentage of silt, such as the loess soils, are usually easily kept in the best of physical condition, while soils with a high percentage of clay are plastic, retentive of moisture, with a strong tendency to form clods when worked in a wet condition and to shrink and crack in a period of drought.

However, the data afforded by a mechanical analysis do not enable the farmer to fix unerringly on definite methods of soil management. In a general way he can determine whether his soil is heavy, whether it is likely to leach or whether it will pulverize satisfactorily under proper cultivation. The investigations conducted by the Bureau of Soils in recent years show that the adaptability of certain soils for special crops can be determined in large measure by a mechanical analysis.

Many different methods of mechanical analysis have been employed by European and American investigators. Two of the American methods which have given very satisfactory results are known as the Osborne method (Rep. Experiment Station, Conn., 1886, 141; 1887, 144; 1888, 154; Wiley op. cit., 196), and the Hilgard method (American Journal Science and Art, 1873, 288, 333; California Experiment Station Report, 1891-92, 248; Wiley, op. cit., 225; pp. 366-369, following).

A simple method of analysis which, with a few modifications, is extensively in use at the present time is described as follows: Thoroughly mix, on a heavy paper or oilcloth, the sample of air-dried soil to be analyzed; take from the well-mixed mass about 100 grams of soil and weigh accurately; roll the sample with a wooden rolling-pin and sift it with a 2mm. sieve. Weigh all small stones and pebbles which do not pass the sieve, and determine the percentage of this material.

Place about ten grams of the sifted soil, which is designated as "fine earth," in a crucible, and dry to a constant weight in an oven maintained at 110° C.

Place five grams of the water-free soil in a shaker bottle, and add about 75 cubic centimeters of distilled water and ten drops of ammonia. Exercise care in weighing the sample of soil and in transferring it to the bottle. Place the bottle in a shaking apparatus, and agitate it until a microscopic examination of the contents shows that the soil particles are completely separated and no compound particles exist. "When this condition is reached, the individual particles will appear clear and semi-transparent in the field of the microscope, while any remaining compound particles will be darker and variously colored from the reflected light. This may require twelve to twenty-four hours, or even longer, depending very much on the nature of the soil. As the determination is quantitative, only a small quantity of the liquid is taken from the bottle with a capillary pipette, and mounted on a slide for examination. When the examination is complete, the slide and cover-glass are carefully rinsed with distilled water back into the shaker bottle to recover the small portion of soil taken. Great care is necessary throughout the analysis to prevent the loss of any part of the sample; and for the purpose of comparison and greater accuracy duplicate samples are used."

When no compound particles are found in the samples, transfer the contents of the shaker bottles into centrifuge tubes. Place the tubes in a centrifuge (Fig. 473), care being taken to have the weight

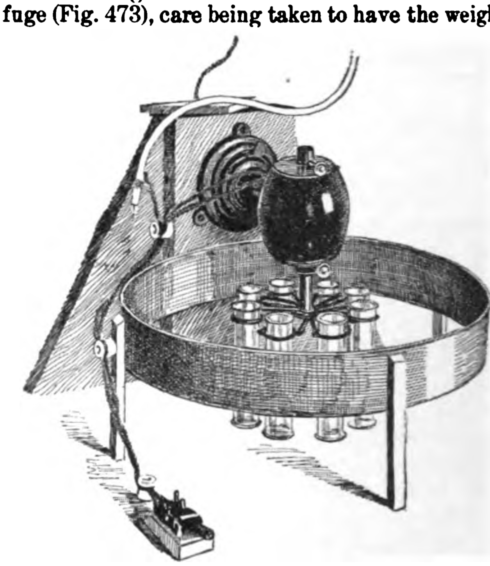

Fig. 473. Centrifugal machine used for separating soil grains of different weights, in physical analysis of soils.

evenly distributed so that the apparatus will run steadily. Rotate the tubes in the centrifuge for two or three minutes at a speed sufficiently high to throw down all particles except those that belong to the grade listed as clay. To determine the speed and time required for this operation, examine the suspended material with the microscope, taking the sample and mounting it as described above.

When it is found that no particles larger than .005 mm. are left in suspension, carefully decant the liquid in each tube into a weighed 400 cubic centimeter beaker, which is numbered to correspond with the number of the tube. Nearly fill the tubes with distilled water, which is delivered with sufficient pressure to stir up the contents of the tubes thoroughly.

Continue to rotate the centrifuge and decant until the contents of each tube are free from particles that belong to the grade designated as clay. Care must be taken to determine very accurately just the time required for the particles larger than .005 mm. to settle, for if the centrifuge is rotated too long, a part of the clay also goes down and the time required to complete the separation is thus greatly lengthened.

Evaporate the contents of the beakers to dryness on the water bath; then dry the residual matter in the beakers to a constant weight in the oven at 110° C., and determine the percentage of clay in the sample of soil.

After the clay particles have been separated as described above, place the tubes in a rack and thoroughly stir the contents by filling the tubes with distilled water that is delivered under pressure.

Examine the suspended material with the microscope and in this way determine the length of time required for all the particles to settle that are larger than .05 mm. Decant into large beakers which are numbered to correspond to the number of the tubes. Repeat the operation of stirring the contents of the tubes and decanting until all of the silt particles are removed.

Set aside the beakers containing the silt for twelve hours or more, or until all of the silt has settled. Then decant nearly all of the water from each beaker; carefully transfer the silt to a weighed and numbered porcelain or nickel dish and evaporate to dryness on the water-bath. Dry the silt in the oven at 110° C. to a constant weight and determine the percentage of silt.

Wash the sand that is left in the tubes after the clay and silt are removed, into weighed and numbered crucibles; evaporate to dryness on the water-bath and dry to a constant weight in the oven at 110° C. Weigh and record this material as total sand.

Separate the sand into the various grades by the use of a series of sieves fitted with bolting cloth, and by this means determine the percentage of each grade.

Color.

The color of soils is determined by the presence or absence of certain compounds. The two principal materials that impart color to soils are humus and ferric oxid. Soils containing large amounts of humus are dark-colored. The presence of humus causes a soil to be gray when dry, but much darker, nearly black, when wet. It often occurs that rich, black prairie soils after the lapse of a few years become lighter colored, owing to improper cultivation or the loss of organic matter (humus). On the other hand, many soils are rendered darker by the addition of manures or by plowing under various crops for green manure. Red soils, such as the residual soils of the southern states, are colored by ferric oxid, and yellow soils, also, but by smaller amounts. A dark soil is generally warmer than one of any other color. This is true because materials that are dark-colored absorb a larger proportion of heat than those that are light-colored.

Experiments show that in the spring black soils near the surface may reach a temperature 8° or 10° higher than light-colored soils during the hours of sunshine. This difference in temperature is an important factor, especially in the spring when the seed-bed is often so cold that the germination and growth of the crop are affected. When other conditions, such as drainage and lay of the land are the same, soils of a dark color are earlier than those of a light color. Although some black soils are unproductive because of the presence of materials injurious to vegetation, such soils as a rule are fertile, owing to the high percentage content of humus and of nitrogen. Hence, color may serve, in a measure at least, as an indication of fertility, a fact that is well recognized by farmers everywhere.

Relation of soil to water.

One of the chief functions of the soil is to supply growing plants with water. Practically all of the water used by a plant is taken up from the soil by the roots. In very few regions is there an ample supply of water furnished by the rainfall during the entire period of the growth of the crop. The water from the reserve supply in the soil is that which more than any other determines the yield of the crop. This is true because the water stored in the soil must be drawn on largely to meet the deficiency resulting from a shortage in the rainfall.

Owing to the fact that the reserve supply of water is such an important factor in crop production, it follows that the capacity of a soil for storing water and its power of supplying this water to growing crops, are points worthy of careful consideration. It is well to note that the water-holding capacity of most soils can be regulated to some extent by the farmer in cultivating and manuring, and the recognition of this fact is now becoming general.

A large supply of water is drawn from the soil by plants, because:

(1) A living plant contains a large proportion of water—generally more than 75 per cent of its weight.

(2) Large quantities of water must pass through the plant in order that the food solution in the soil may be carried to the leaves, and the substances that it contains may be converted into organic matter. This water loss takes place by transpiration from the leaves and growing shoots.

Careful and extended experiments in this country and in Europe have shown that 300 to 500 tons of water are taken from the soil by the various crops for each ton of dry substance produced. The following table gives the mean amount of water used by various crops in producing a ton of dry matter:

	No. of trials	Water used per ton of dry matter	Water used	Dry matter per acre	Acre-in. of water per ton of dry matter (King)
		Tons	Inches	Tons	
Barley . . .	5	464.1	20.69	5.05	4.096
Oats	20	503.9	39.53	8.89	4.447
Maize . . .	52	270.9	15.76	6.59	2.391
Clover . . .	46	576.6	22.34	4.39	5.0899
Peas	1	477.2	16.89	4.009	4.212
Potatoes . .	14	385.1	23.78	6.995	3.399
Average .		446.3	23.165	5.987	3.939

The direct evaporation of water from the soil is a source of loss of no little importance in a dry, hot season. Water taken from the soil by this process is a loss additional to that transpired by the crop. The following results were secured at the Iowa Experiment Station in an experiment to determine the total amount of water removed from the soil by evaporation and transpiration:

One ton	Tons of water lost	Acre-in. of water lost
Clover hay	1,560	13.7
Air-dried corn fodder	570	5.0
Oats and straw	1,200	11.0

Water occurs in the soil in three forms: (1) Gravitational or hydrostatic water; (2) capillary water; (3) hygroscopic water.

The gravitational water is that which fills the pore spaces between the soil grains and is moved by gravity. This water is of value to growing

Fig. 474. The grasp of the plant on the particles of earth. A grass plant pulled in a garden. Most of the roots were broken; but the tenacity of the root-hold is shown by the great ball of soil that was raised out of the ground.

crops when it is so near the surface that it can be carried by capillarity to the zone of soil occupied by roots. When gravitational water is too near the surface it saturates the zone which should be occupied by roots, and this proves exceedingly harmful to plant growth.

Capillary water is that which surrounds the soil particles and root-hairs as a thin film, and is moved by surface tension through the soil from a moist to a less moist area, even in opposition to gravity. Capillary water furnishes crops and soil organisms with the moisture that they require for growth and activity, and it is in this water that the plant-foods derived from the soil are held in solution and are carried to the plants through the roots.

Hygroscopic water is that part of the soil water that is found on soil particles but that is not subject to movement by gravitation or capillary force. One authority says that "moisture in this form possibly plays an important part in the actual solution of plant-food from the soil and fertilizer grains, because it is this portion which lies in immediate contact where the action must take place." However, the amount of hygroscopic water in the soil is usually small, and it is now thought that it is not a source of supply of moisture for growing plants.

The water capacity of soils is measured by the total pore space, and varies widely in different soils. Soils that are saturated hold 4 to 6 acre-inches per acre-foot of soil, or 20 to 32 pounds per cubic foot. The volume of water in a given volume of soil is lowest in a sandy soil, is somewhat greater in a loam or clay, and reaches its highest point in a soil that contains a large amount of organic matter. Soils that are adapted to crop production are never saturated, and hence the water capacity of soils under field conditions is much less than the total water capacity of the same soils.

The moisture in the soil is subject to three types of movement: (1) gravitational; (2) capillary; (3) thermal. The water that falls on the surface of the earth is in part carried by percolation downward through the pore spaces by the force of gravity; a second part is held by surface tension around the soil particles and root-hairs, and thus increases the amount of capillary water; a third part is evaporated by heat.

The rate of percolation is determined by the character of the soil and the amount of rainfall. As a rule, water percolates most rapidly through soils in which the retention of water is least. Water percolates slowly through fine-grained soils because the spaces between the particles are so small that friction greatly retards the downward movement of the water. In many arable soils percolation is facilitated by channels opened by earthworms and by the roots of plants, and by crevices and cracks formed in time of drought. Excessive percolation is undesirable for the reason that the soil water is carried beyond the reach of the roots; and further because soluble plant-food may be leached out. Deficient percolation is also harmful because under such conditions the soil is likely to be cold and wet and insufficiently ventilated. Losses due to excessive percolation may be prevented in large measure by changing the texture of the soil by cultivation and by the addition of manures, and in the case of an open, porous soil by compacting it by rolling.

The capillary movement of soil moisture is slower than the movement due to percolation, and is slower in dry than in wet soil. In obedience to the laws of capillary attraction and surface tension, water may be moved downward or sidewise as freely as upward. As a rule, this movement is from a soil where the films of water are relatively thick to one where the films are thinner. It is the capillary movement of water from the hydrostatic supply into the zone occupied by the roots of plants that is of the greatest importance.

There is wide variation in the rapidity of movement and the distance to which water is carried by capillarity in different soils. For example, water rises rapidly through sand for a short period, but is not raised to any considerable height owing to the large spaces between the soil particles. In finer soils, such as clays and silts, the water rises more slowly, but the movement continues for a long time and the water is raised to a considerable distance.

The water-supply which is available for crops is influenced by different methods of cultivation. The moisture already in the soil is conserved by tillage, by the formation of mulches and by establishing windbreaks.

The relation of soil to heat.

The influence of the temperature of the soil on crop production is a factor of considerable importance. The life processes of a plant are practically suspended below a certain minimum temperature, which is about 40° F. for most cultivated crops. Above this temperature all the vital activities, as germination and growth, increase until the optimum is reached. Above this point these life processes decrease in activity until finally the point is reached when they cease. The soil is a great factory that has its production vastly increased as the temperature rises. This is true of germination and the subsequent development of plants, of bacterial development and nitrification, of the movements of water, air and salts, and of chemical processes, as oxidation. The minimum temperature at which corn germinates and also the minimum for its growth is 48° or 49° F. Its optimum is about 93°.

In addition to this direct influence on the growth of crops, the soil temperature has a controlling influence on the low forms of life,—fungi and bacteria,—which exist in the soil in vast numbers and which convert organic matter into forms available for the plant. The formation of nitrates is one of these processes in which the temperature of the soil is a controlling factor. Nitrification begins at 41° F., but is most active at 98° F.

The temperature of the soil is best obtained in the field by an ordinary glass thermometer. Several readings should be made at each depth, and the average of these readings recorded. This method is recommended for the reason that unaccountable variations occur, especially on rough ground. When soil temperatures are to be determined to a considerable depth it is advisable to use the regular wood-cased soil thermometers, and in certain experiments the electrical thermometer is very convenient. Observations made on sandy loam show that the heat enters the soil at the rate of about one inch an hour. At a depth of one foot the maximum temperature is reached at midnight and the minimum at noon. The daily variation at this

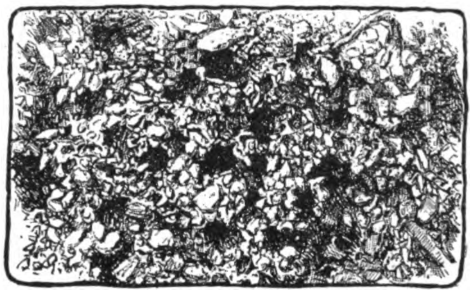

Fig. 475. The porosity of a hard lump of soil as seen through a magnifying-glass.

depth was observed to be about 1°, while at one and one-half inches deep it was 16°.

As the depth at which the temperature is taken increases, the daily changes gradually disappear; at about 3 feet and below this point, only variations due to the seasonal changes are noted. A point is at last reached where the temperature is unchanged throughout the year. The position and temperature of this point vary much in different climates and in different soils. In hot climates there is a warmer soil above this point and a cooler soil below it. In cold climates the soil is cooler above and warmer below.

The mean temperature of the surface of the soil is not far different from that of the air above it. However, at any one period of observation it is almost certain that a difference in temperature will be noted. In fine weather, the mid-day and afternoon temperature of the surface soil is much above that of the air. In some instances, the temperature of the soil is higher during cloudy weather. The minimum temperature reached by a dry, bare soil, a point that is reached in the early morning, is below that of the air if the weather is clear.

The sources of the heat of the soil are the internal heat of the earth, the sun, and decaying vegetable matter. It is difficult to estimate to just what extent the internal heat of the earth, which itself is very great, affects the temperature near the surface of the earth. However, the amount of heat from this source is insignificant, is a constant factor and is entirely beyond the control of man.

Decaying organic matter furnishes some heat to the soil. For example, manure heats the soil to a limited extent when it is spread on the surface and plowed in. Georgeson found that ten tons of manure per acre during the first twenty days produced an average excess of temperature over the unmanured plots of .93° F. The increase in temperature was greatest during the first five days and thereafter rapidly diminished. It is evident from this experiment that the increase in temperature produced in the soil by decaying organic matter is not great and is practically a negligible factor. The manured plots in this experiment became slightly cooler after the first few weeks. This result was attributed to the cooling effect of the larger amount of water held by the manure. The plowing in of green crops has an effect on the temperature of the soil similar to that produced by an application of farmyard manure. The greatest increase in temperature from organic matter occurs when the soil is porous, moist and at a temperature not below 50° F. The increase in temperature is therefore greatest in summer time, all processes of fermentation and oxidation being then most active.

The sun is by far the most important source of heat for the soil. When its rays are nearly vertical there is tropical heat; when its rays are withheld, the land is locked in snow and ice. The heat received at the surface passes downward by conduction. The larger the particles and the more compact the soil the more rapid the movement due to conduction. Water also aids in an open or sandy soil in the conduction of heat downward. This is true not because water itself is an excellent conductor, but because it is a better conductor than air. In a peaty soil, because of the large amount of water that is held by the organic material, heat penetrates into the subsoil very slowly. A fine, dry, loose soil is an exceedingly poor conductor of heat. Soils of this class have the surface much heated by the sun's rays, but this heat penetrates to a comparatively shallow depth. On the other hand, a consolidated, stony soil is an excellent conductor of heat. Experiments show that a gravelly soil is one especially suited for the production of early garden crops. This fact is due to the rapidity with which such a soil is warmed in early spring.

Fig. 476. The texture of the soil. The upper sample is loose garden loam. The lower is hard pulverized clay. Both were given the same quantity of water and allowed to dry. The loam remains loose and crumbly; the clay puddles and cracks.

Heat passes away from the surface soil by radiation. The character of the soil has almost no influence on the radiation of heat. A moist soil radiates heat much better than a dry one. A rough, uneven surface favors radiation.

There are several factors that affect the temperature of the soil, in the same way and at the same time that they affect the general temperature and climate of a locality. The first of these is altitude. A high altitude means a lower temperature. Hot or cold winds may prevail.

The temperature of the soil is also affected by its texture. A coarse, gravelly soil, because of its low specific heat and superior conduction, is more uniform in temperature and has a warmer subsoil than a finer soil or one that contains a large amount of organic matter. However, texture is never the only factor that influences the temperature of the soil, because it is well known that a wet soil is a cold soil. A wet soil warms up more slowly than a dry soil, for two principal reasons: (1) the high specific heat of water (four or five pounds of soil will be raised in temperature to the same degree as one pound of water if both soil and water receive the same amount of heat); (2) because of the evaporation which takes place from a moist or wet soil. To convert one pound of water into vapor requires 966.6 heat units; if this number are withdrawn from a cubic foot of saturated clay soil the temperature of the soil is lowered approximately 10.3° F. The chief reason why an undrained soil is colder than one well-drained is the cooling effect associated with the larger evaporation of soil moisture. King shows that the differences in temperature in favor of a drained soil may amount to 2.5 to 12.5 degrees.

By reason of the fact that a light sandy soil is well drained, this type of soil is warmest in the spring and makes a desirable truck field. Well-nigh perfect drainage is effected in this type because of its texture; there is less evaporation from the sandy soil and hence it warms up rapidly early in the season.

Color has a marked influence on the temperature of the soil. A plot of soil coated with lime is often 5° to 10° cooler, on a bright day, than a plot covered with lamp-black. This difference is due to the fact that the light-colored soils reflect part of the sun's rays, while the dark-colored soils absorb practically all of them. On cloudy days no difference between the temperatures of these two plots would be noted. At night they will cool to the same temperature. Radiation is not affected by color. The general tendency is for humus to make the soil darker and hence to increase the temperature. The large quantity of water that is held by the humus, on the other hand, tends to diminish the increase in temperature due to the darker color of the soil. A covering of grass or growing crops tends to make the soil cooler in the daytime and warmer at night, and it also tends to lower the temperature somewhat throughout the summer.

Tillage has a marked effect on the temperature of the soil. Conduction is lessened by cultivation and therefore the heat tends to remain in the surface soil. Radiation is increased by cultivation and hence the loss of heat to the air is increased. Investigations at the Iowa Experiment Station have shown that it is possible to warm a loam soil in the spring by early cultivation, but only to a limited extent. The amount of water in the surface soil, and consequently the amount of evaporation, seems to be the controlling factor rather than the kind and extent of cultivation. Rolling compacts the soil and causes it to warm deeply at a more rapid rate. In extreme cases a difference of 10° F. in favor of the rolled over the unrolled soil has been found in spring at a depth of one and a half inches.

Relation of the soil to air.

When the interstitial spaces between the particles of soil are not filled with water, or when they are only partially filled, they contain air. The air which circulates in the soil differs in composition from the air above the surface. As a rule, the soil air contains less oxygen and more carbonic acid, ammonia and vapor of water. The increased amounts of carbonic acid and ammonia have their origin in the organic matter or humus. A soil is not in the best condition for the production of crops unless there is, within its depths, a free circulation of air. This is true because oxygen in the soil is as essential for the life of the plant as it is for the animal. Without free oxygen the seed fails to germinate and in a short time rots; the roots fail in their appointed tasks; the innumerable host of soil bacteria perish, whose work it is to change the nitrogen of decaying organic matter into an available form; and the germs on the roots of the red clover and other leguminous crops, which supply available nitrogen at the lowest cost, do not accomplish their important work.

When the soil is full of water to within a few inches of the surface there can be no circulation of air among its particles. Adequate ventilation can be provided for such a soil only by drainage. Drainage ventilates the soil by lowering the ground water three or four feet and thus makes it possible for the roots of plants to penetrate the soil more deeply. In time these roots die and decay and afford passageways throughout the soil for the ready movement of the air. Thus conditions are secured that promote the growth of plants, facilitate the work of the unlimited host of soil bacteria and hasten the formation of available plant-food.

According to King, soil ventilation is brought about in several ways and by different agencies. He names the following: (1) The slow process of diffusion; (2) the expansion and contraction of soil air due to change in temperature; (3) the expansion and compression of the air due to barometric pressure; (4) the suctional effect of the wind; (5) the air absorbed by rain water carried into the soil when percolation takes place; (6) when water drains away from a soil or is carried upward and out by capillarity or root action it acts by suction to draw into the soil a volume of air equal to that of the water which flows out.

Odor and taste.

Soils possess a characteristic odor due to the presence of organic matter. Warington says that the odor of soil is due to a volatile organic substance, the chemical nature of which has not been satisfactorily ascertained. This substance is said to belong to the aromatic family of plants.

The chemical composition of the soil determines in large measure its taste. Thus, a peaty swamp soil that is poorly drained is likely to have a slightly sour taste, due to the presence of organic acids. The alkaline compounds in alkaline soils give to soils of this class a characteristic taste.

Literature.

The reader is referred to the following publications: Physics of Agriculture, F. H. King; The Soil, F. H. King; Physical Properties of Soil, Robert Warington; The Soil, A. D. Hall; Rocks and Soils, H. E. Stockbridge; Rocks, Rock-weathering and Soils, Geo. P. Merrill; Agricultural Analysis, H. W. Wiley; Bulletins of the Bureau of Soils, United States Department of Agriculture.

SOME OF THE CHEMICAL PROPERTIES OF SOILS

By *Harry Snyder*

Chemistry is usually defined as that science which concerns itself with the changes that take place in nature when matter completely loses its identity. Such changes affect the composition of the ultimate particles of which substances are composed. Numerous changes of this character take place in the soil. Rocks decay and become incorporated with animal and vegetable matter to form soils of various degrees of fertility. It is well known that some soils are more susceptible to changes than others because of differences in composition which either accelerate or retard chemical changes.

Those changes which affect the composition or make-up of a material are called chemical changes, while those which affect the form but not the composition are called physical changes. There is a very close relationship between the chemical and physical properties of soils, and it is often difficult to discuss one without considering the other, as a chemical change brings about different physical conditions, and a physical change is often necessary before a chemical change can take place. When a chemical change takes place in the soil, the elements of which the compounds are composed are rearranged and united in a different way from what they were, while in a physical change the combination of the elements is unaltered. For example, the action of water in disintegrating limestone or any other mineral is purely physical, but when the water enters into chemical composition with the rock or mineral, as it does when rocks decay to form soils, then the process is chemical. As a result of the chemical changes that are continually taking place in the soil, new compounds are formed, some of which are more valuable than others as plant-food.

In a brief consideration of the chemical properties of soils, some of the essential points to consider are: (1) Factors which cause chemical changes to take place, (2) the extent to which these factors are capable of being controlled, (3) the products formed as the result of chemical changes and their relation to crop growth, (4) the general chemical composition of soils, (5) the availability of the plant-food, and (6) the influence of different systems of farming and tillage on the chemical properties of soils.

To the agriculturist, the general relationship of the chemical properties of soils to such problems as maintenance of fertility and crop production, is of more immediate importance than a study of the purely scientific aspects; but too frequently generalizations are attempted that are not founded on the necessary preliminary scientific inquiry, and in the study of soils, as in other subjects, this tendency to draw premature conclusions from insufficient data has been noticeable.

Factors causing chemical changes.

The factors which cause chemical changes to take place in soils and which exert an influence on their chemical properties are: Water, air, substances in solution, and plant and animal life. These factors are assisted by physical agencies, as heat, cold, wind, and water acting mechanically. All of these, acting jointly, have caused rock decay and soil formation. The workings of these different agencies are discussed under the head of geological formation of soils. [See Origin and Kinds of Soils, page 324.]

The chemical action of water has been an important factor in soil production, resulting in the formation of hydrated silicates, as the zeolites, which in turn undergo further change and become available as plant-food. Thus it is that, in the decay of rocks, water takes an essential part by entering into the composition of the resultant minerals, changing their properties and preparing the way for other changes to take place, so that ultimately plant-food may be rendered available for crops. When substances are dissolved in water, they possess different properties, due to ionization, and as a result the dilute solution becomes a potent factor in promoting chemical changes. While nearly all rocks are practically insoluble in water, there are always present in the water materials which act chemically on minerals and other substances.

Acting jointly with water is air, which contains a number of elementary gases and simple compounds. The oxygen of the air promotes oxidation, and the carbon dioxid dissolved in water acts as a solvent and enters into chemical combinations, forming carbonates with liberation of other elements. Some of the iron compounds, as the carbonate, are soluble in waters that contain carbon dioxid in solution; when such waters come in contact with the air, a reddish brown deposit of hydroxid of iron is formed. This action takes place in many well waters when exposed to the air, and illustrates one of the numerous chemical changes brought about by the joint action of water and dissolved gases.

Plant and animal life processes cause many chemical changes to take place in soils. Wherever plant life and animal life have been particularly active, large amounts of organic residues in the form of carbon compounds accumulate in the soil, where they undergo decay with the formation of compounds known as humus, which exert a characteristic influence on the properties of soils. Indirectly humus is an important factor in promoting fertility.

When animal and vegetable matter decays, organic acids are formed. If soils contain the requisite basic material, these acids unite with the mineral matter, producing organic salts or humates. In many soils containing large amounts of decayed vegetable matter, an appreciable amount of the mineral matter is combined with the organic acid formed through processes of decay. When the soil contains the requisite amount of basic mineral matter, the accumulations of vegetable matter result in the formation of soils of high productiveness; but when the soils are deficient in active basic materials, the organic matter decays with the production of humic acids which, if present in too large amounts, are injurious to many farm crops. In the application of lime, wood ashes and other chemicals to correct and improve acid soils, the object is to furnish the necessary basic material to combine with the free organic acids of the soil. Soils of the highest productiveness do not contain an excessive amount of either free acid or alkali. A slight amount of the free alkaline compounds in a soil, such as calcium carbonate, is desirable, as it prevents the soil from becoming acid when farm manures are applied. Soils of such character, produced from disintegrated miscellaneous rock materials, especially by glacial action, are of the highest productiveness and respond the most generously to cultivation and the application of farm manures. This is largely due to the desirable chemical changes readily taking place, mainly through the action of humus-forming materials in the soil, with liberation of such elements as calcium, potassium and phosphorus in forms available as plant-food.

Experiments have shown that whenever manure is added to the soil, the organic acids formed from the decay of the manure unite and chemically combine with a portion of the potassium, calcium and other mineral elements of the soil. Experiments at the Minnesota Experiment Station show that crops such as wheat, oats and barley are capable of extracting and utilizing for food purposes the mineral elements, as potassium, calcium and phosphorus, which are combined with the humus. In many soils of high productiveness, as the prairie soils in the central western states, are appreciable amounts of mineral plant-food in combination with the humus. When soils have long been under cultivation to such crops as wheat, corn or cotton, the humus content is reduced and the crop-producing power of the soil impaired. The action of organic matter on soils, in the form of farm manures and crop residues, has been one of the most important factors in promoting the neces-

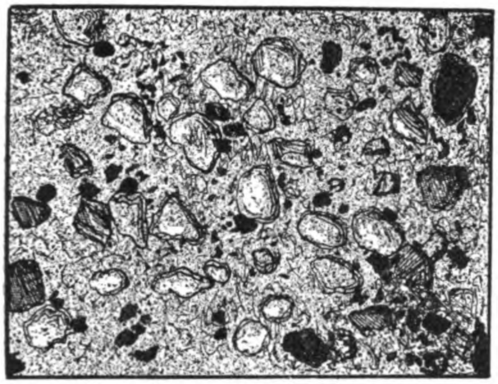

Fig. 477. Soil before removal of humus, showing soil particles imbedded in organic matter.

sary chemical changes in soils which result in the liberation of plant-food.

Control of the factors.

Some of the factors that cause chemical changes to take place in soils are under the control of the cultivator, and it is possible for him to assist nature to induce such changes as will result in the liberation of plant-food and the production of larger crops. While tillage brings about important physical changes, improving the tilth of the soil also promotes many chemical changes. By increasing the air spaces in the soil, oxidation of both the mineral and the organic constituents is encouraged. The supply of the element nitrogen is influenced by cultivation to a greater extent than that of any other plant-food element. The main store of soil nitrogen is present in combination with carbon, hydrogen and oxygen in the form of humus. When the humus decays, the nitrogen unites with oxygen and a base element, as calcium or potassium, to form nitrates. This process, known as nitrification, is induced by the workings of micro-organisms and results in making the inert humic nitrogen of the soil active and available for plant-food in the form of nitrates. The rate of nitrification can be controlled to a large extent by tillage. Thorough plowing and pulverizing the soil aids nitrification; the addition of manures also favorably affects the process. Soils deficient in the active alkaline compounds of potassium and calcium do not contain a large supply of available nitrogen, because there are no basic compounds to form nitrates. Such soils are improved by an application of alkaline fertilizers which promote nitrification. Many soils that have been under continuous grain-cultivation for a long time contain comparatively small amounts of nitrogen and produce poor crops because of excessive losses of the humus, of which nitrogen is a component part.

By varying the method of tillage, the rate of oxidation of the humus and the process of nitrification can be either accelerated or retarded. The effect of tillage on the supply of nitrogen in the soil is better understood than is the case with the mineral elements, as potassium, phosphorus and calcium. Tillage and the application of manures, however, exert a marked influence on these elements, largely through the formation of humates. Since soils are mechanical mixtures of disintegrated rocks and minerals, and animal and plant remains, it follows that the chemical changes which take place necessarily vary with the nature of the materials of which the soil is composed, and a chemical change which readily takes place in one soil may fail to take place in another because of lack of the necessary reacting substances. Hence it is that all soils do not respond alike to the same kind of treatment.

Relation of products formed to crop growth.

Soils that possess defects, as excessive amounts of strong acid or alkaline compounds, are those which, as far as crop-production is concerned, have an unbalanced chemical composition. In order that such soils may be made productive, they must receive the necessary treatment in the way of tillage and application of fertilizers that will reduce the excess of either acid or alkaline matter. While the physical condition of the soil, as its permeability, tilth and its relation to heat and cold, is of the utmost importance in plant-production, the condition of the soil as to acidity or alkalinity, and the forms in which the mineral matters are present, are of equal importance. Many soils in good physical condition fail to produce remunerative crops because of excessive amounts of free acid or alkaline compounds and a

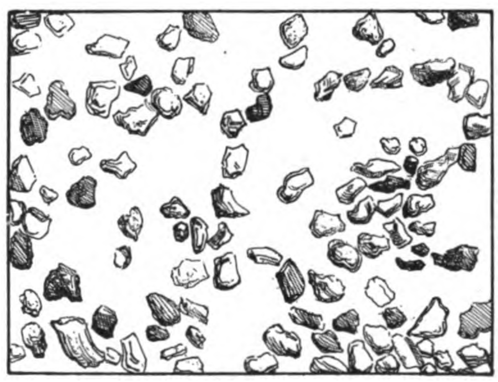

Fig. 478. A certain soil after removal of humus.

lack of the requisite forms of mineral matter. On the other hand, soils that contain a large amount of inert plant-food may fail to return good crops because of poor physical condition. Soils of high productiveness always have a well-balanced chemical composition and possess certain definite physical properties. The physical condition, as well as the chemical composition of a soil, is capable of being changed by tillage, and so closely are the chemical and physical properties related that those methods of tillage and manuring which improve the physical condition are alike beneficial in bringing about important chemical changes. Particularly is this true in the liming of heavy clays, when the element calcium assists in liberating the element potassium, promotes nitrification and also, by agglutinating the fine clay particles and forming compound soil particles, improves the tilth and permeability of the soil.

Chemical composition of soils.

When rocks disintegrate to form soils, the process generally ceases with the formation of definite chemical compounds. In dealing with the elements in the soil, we are not considering the elements in the free state, as they are rarely found in that condition, but they are present in the form of more or less complex compounds. The same element may be present in several different combinations in the soil. For example, the element potassium may be present as a part of feldspar rock, or in its products; it may also be present as a constituent of mica or of some of the secondary or derivative minerals known as zeolites, or as a simpler silicate, or in small amounts in such forms as the chlorid, sulfate or nitrate, as well as in a number of other forms. It makes a great difference, as far as fertility is concerned, in what form the element is present. If it is present as a constituent of feldspar, mica or some of the silicates, it is of no immediate value in the production of crops; while in other forms, as some of the zeolites and salts, it is either available as plant-food or capable of being made so by proper cultural methods.

Sodium is present in soils in forms similar to potassium, and while it is an element of minor importance in plant nutrition it nevertheless takes an important part indirectly in soil fertility, inasmuch as it enters into many chemical changes which are necessary for rendering plant-food available, as in nitrification.

Aluminum is present in many soils, particularly clays, in larger amounts than any other basic element. It is estimated that six to ten per cent of the earth's crust is composed of this element. Aluminum is combined mainly with silicon and oxygen, forming silicates, and also with the metals, as iron, potassium and calcium, forming double silicates, of which there are a very large number.

Calcium occurs in soils mainly as carbonate or disintegrated limestone. In some soils the calcium is in combination with the silicon, forming silicates, in which case it is often necessary to add to the land a more active form of calcium, as gypsum, or land plaster, or some form of lime. The active calcium compounds take an important part in rendering soils fertile, by supplying an element of plant-food, correcting acidity, promoting nitrification and improving the mechanical condition of the soil.

Other base-forming elements in the soil are iron, magnesium and manganese. They are combined mainly with the silicon as silicates, and are met with to a less extent in other forms.

Silicon is present in soils in the largest amounts of any of the elements except oxygen. With oxygen it forms silicon dioxid, or common white sand. Silicon and oxygen together make up about 75 per cent of the mineral matter of the soil. While silicon, as far as known, takes no direct part in plant nutrition, it is associated and combined with all the essential elements on which plants feed. Soils are largely composed of silicates of various degrees of complexity. A few of the simpler are soluble in water, but most of them are insoluble and are decomposed only by the joint action of fluxes and chemicals at a high temperature. The composition and general properties of the silicates are imperfectly understood. They are a very large class of compounds derived from a number of forms of silicic acid. The most common minerals, such as quartz, feldspar, kaolin and mica, are derivatives of silicic acid.

Phosphorus is combined principally with oxygen and calcium, forming calcium phosphate, and to a less extent with other elements, as iron. The phosphorus compounds of the soil are present mainly in an insoluble condition, but by the action of manures, crop residues and tillage, the phosphorus, if present in sufficient amounts, is rendered available, provided the soil is not too acid in character.

Sulfur and chlorin are both present in small amounts, as are also other acid-forming elements.

From these brief statements, it will be observed that the fifteen or sixteen elements of which soils are composed are combined in a great many different ways, forming definite chemical compounds which have different values as plant-food, possess different chemical properties, and act in different ways in bringing about desirable chemical changes in the soil.

Availability of the plant-food elements.

The elements which are found in the largest amounts in soils are silicon, aluminum and oxygen. These elements make up 80 to 90 per cent of the mineral constituents of average soils. They do not enter directly into the composition of plants or serve any functional purposes, the oxygen in plant tissues being derived from water. Hence it is that over 80 per cent of the mineral matter of the soil is inert material which does not contribute to plant growth. The remaining elements, utilized largely in crop nutrition, as potassium, phosphorus, calcium and nitrogen, are present in comparatively small amounts; in many cases they do not jointly make up one per cent of the weight of the soil. Less than one pound per hundred of average fertile soil is composed of the most important mineral elements. Thus it is that the heaviest draft on the soil falls on the elements that are present in the smallest amounts.

In the chemical analysis of soils, the general composition is determined and also the percentage amounts of the oxids of the various acid and base elements. With many soils this does not give sufficient data as to the probable condition of the plant-food. Various attempts have been made to determine the more active and available forms of plant-food by the use of solvents, as dilute organic and mineral acids. Because of the complex and variable nature of soils, no one solvent has been found that will extract alike from all soils the available plant-food. Nevertheless, the chemical analysis of a soil is often very valuable in determining when there is too small an amount of any element, as deficiency of nitrogen and phosphorus, or in detecting the presence of injurious chemical compounds, as free acids or strong alkaline salts.

In interpreting the analysis of a soil, the reaction, as neutral, acid or basic, should first be noted, and then the probable condition of the lime, as indicated by the amounts of calcium oxid, carbon dioxid, and sulfuric anhydrid present, or as determined by special tests. If the soil is mildly alkaline, with a fair amount of lime in the form of carbonate, and is not deficient in total potash or phosphoric acid, the plant-food can be kept in an available condition by the use of farm and other humus-producing manures, while the nitrogen is acquired from atmospheric sources by the production of leguminous crops. Such soils, if in good physical condition, as they usually are, are of the highest fertility. In the table it will be noted that most of the soils of highest fertility have these chemical properties:

Every soil contains naturally some plant-food as the result of the disintegration changes which are continually taking place. It is this fertility that represents the minimum crop-producing power of the soil. By the addition of farm manures, judicious rotation of crops to increase the stock of humus and, in case the soil has an unbalanced chemical composition, by the use of amendments or commercial fertilizers, the natural fertility can be greatly increased and a large amount of cumulative fertility added to the soil. A soil is fertile only to the extent to which it contains natural and cumulative fertility. In judging the fertility of a soil, the crops which have been produced and the general system of farming which has been followed are important factors to consider.

Many chemical changes are induced in soils by the action of commercial fertilizers containing soluble salts. These changes are usually discussed under the general topic of fixation, the chemical change that takes place when soluble fertilizers are added to soils and become insoluble. This is usually brought about by replacement of some of the elements in the soil with equivalent amounts of other elements in the fertilizer. Many of the fixation changes are beneficial for crop production, and they also explain the chemical action of indirect fertilizers. When long continued, commercial fertilizers, through processes of fixation, may materially modify the chemical and physical properties of soils, as has been shown in the experiments at Rothamsted.

CHEMICAL COMPOSITION OF SOIL TYPES.

	Cotton soil S. C seacoast		Brazos river soil, Texas		Washington surface soil	Kentucky soil		California fruit soil		Soil from Red river valley	
	Surface	Subsoil	Surface	Subsoil		Virgin	Cultivated	Surface	Subsoil	Surface	Subsoil
Insoluble matter	93.61	94.46	68.45	77.57	76.49	77.01	81.01	72.72	73.57	47.64	41.21
Silica (soluble in Na_2CO_3)	1.63	1.89	14.79	0.84	13.66	9.33	0.00	14.53	6.44	15.43	8.37
Potash	0.05	0.14	1.10	0.44	0.63	0.30	0.32	0.68	1.35	0.54	0.25
Soda	0.11	0.15	0.23	1.82	0.37	0.39	0.19	0.24	0.25	0.45	0.48
Lime	0.03	0.02	5.62	0.18	1.08	0.40	0.32	1.15	0.57	2.44	7.45
Magnesia	0.04	0.04	1.86	3.18	0.72	0.34	0.39	1.30	0.87	1.85	4.48
Iron oxid	0.40	0.34	3.21	8.28	4.55	3.30	2.96	9.29	4.93	4.18	3.48
Alumina	1.93	2.52	7.68	0.13	7.52	6.70	5.92	8.29	8.72	7.89	10.72
Phosphoric anhydrid	0.03	0.01	0.14	0.00	0.14	0.50	0.38	0.12	0.07	0.38	0.17
Sulfuric anhydrid	trace	trace	0.05	0.00	0.00	0.17	0.16	0.07	0.04	0.11	0.10
Carbonic anhydrid	0.00	0.00	3.99	1.71	0.00	0.10	0.06	0.00	0.00	2.42	14.26
Volatile matter	1.69	1.04	2.50	2.50	3.61	10.59	8.33	6.09	2.91	15.55	6.22
Humus	0.70	0.00	0.00	0.00	0.99	2.21	2.01	1.09	0.00	5.34	0.89
Nitrogen	0.00	0.00	0.00	0.00	0.10	0.27	0.18	0.00	0.00	0.38	0.11

From Soils and Fertilizers, Snyder, pages 81–82.

The available plant-food necessarily varies with the chemical changes that are continually taking place in a soil. When these changes occur either naturally or through judicious manuring and tillage, so that the supply is sufficient to meet the demands of growing crops, then the soil is one of high fertility. Many soils produced from certain rocks and minerals are slow to decay, deficient in plant-food, or have undergone previous chemical changes with liberation of the plant-food and subsequent loss by leaching. Such soils are of low fertility.

A number of important chemical changes are also brought about in the soil by the continued production of some crops that abstract large amounts of certain minerals, leaving others to combine in different ways. Soils that are neutral may, through long periods of injudicious cropping, become acid in character by excessive losses of the basic elements, as potassium and calcium. Crops exert a material influence on the chemical composition and properties of soils. Although the exact forms in which the different elements are present are not known, the influence of different methods of tillage and systems of farming on fertility is well known, and the results are particularly pronounced when soils have been farmed in different ways for long periods.

Influence of systems of farming on the chemical properties.

Studies that have been made on the influence of different systems of farming on the composition and crop-producing power of soils have shown that when the soil continually produces a plowed crop and no farm manures are used there is a rapid decline of the humus and also of the element nitrogen, one of its component parts. Along with the loss of nitrogen and humus, there are also losses of phosphorus, potassium and other elements in chemical combination with the humus. The loss of humus from the soil also affects the physical properties, particularly the relation of the soil to heat and water. The use of farm manures, green manures and crop residues for maintaining and increasing the fertility, through the agency of the humus thus added to the soil, has been resorted to by tillers of the soil from the earliest times, and it is without doubt one of the most natural, economical and practical ways of maintaining fertility. This practice is scientifically well founded.

Excessive decay of the humus, favored by injudicious methods of cultivation, causes an excessive loss of nitrogen and a loss of plant-food in humate forms. This often results in a decline in yield of farm crops. A moderate rate of decay of humus in a soil is desirable so as to render both the nitrogen and the mineral plant-food available.

In the case of exclusive wheat-farming in the central western states, it has been found that soils having produced twenty or more crops of wheat continuously, contain a third to a half less nitrogen than similar and adjoining soils that have never produced a cultivated crop. Exclusive corn- or cotton-production also rapidly reduces the nitrogen and humus content of soils and leaves less mineral matter in combination with the humus. In many cases the loss of nitrogen has been hastened by long practice of summer-fallowing, which temporarily increases the yields of succeeding crops, but in the end results in the unnecessary loss of nitrogen. Summer-fallowing causes the humus to decay rapidly, and thus four or five times more nitrogen is liberated than is used by the next crop. Summer-fallowing causes an increase in the available nitrogen, but a material decrease in the total nitrogen. Hence, if this practice is continued, the original store of nitrogen will be reduced below the point necessary for profitable crop production. If, instead of resorting to summer-fallowing, some green crops are grown and plowed under, as a green manure, a new stock of humus is added to the soil.

Experiments at the Minnesota Experiment Station have shown that when a rotation of crops is followed, the chemical properties of the soil are materially modified. When wheat was grown continuously, an excessive loss of nitrogen occurred, due not so much to the removal of the nitrogen by the crop as plant-food as to the rapid decay of the humus, and the loss of nitrogen through the drainage of soluble nitrogen compounds from the soil and the formation of volatile products through denitrification processes.

In other experiments it has been found that, when grain is raised continuously, for every pound of nitrogen removed by the crop, four to five pounds are lost in other ways. This loss of humus and nitrogen, which combines with carbon, hydrogen, oxygen and mineral matter to form humates, unfavorably changes the properties of the soil both chemically and physically. The losses or gains of nitrogen from the soil when different systems of farming are followed, and the effect of different systems of farming on the composition and form of the mineral constituents of the soil, are among the more prominent causes making soils decline in fertility when cultivated exclusively to one crop, and maintain their fertility for long periods when crops are judiciously rotated and farm manures are used. Farm manures and crop residues are valuable not only for the plant-food which they contain, but also because they combine with and make the inert mineral elements of the soil valuable as plant-food. Thus it will be seen that those systems of farming which best conserve and also develop the latent fertility of the soil are those methods which promote the greatest chemical activity in the soil.

In many cases, commercial fertilizers have been unnecessarily resorted to for the production of crops, when the natural or inherent fertility should have been developed by promoting the necessary chemical changes in the soil so as to acquire a stock of cumulative fertility. Whenever it is more profitable, fertility should be acquired through chemical changes brought about by cultivation rather than purchased in commercial forms. Since the maintenance and utilization of the fertility of soil necessarily form the basis of any rational agricultural system, the chemical changes which influence the fertility are of paramount importance.

Our present knowledge in regard to many of the chemical changes that take place in the soil is limited, but some of the principal changes are well understood and form a part of the basis of our scientific agricultural instruction.

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THE ANALYSIS OF SOILS

By *E. W. Hilgard*

In the laboratory it is possible to resolve soils into their constituent substances, or to determine what those substances are and how they are combined; and also to determine the physical constitution. It is difficult to correlate exactly the findings of the laboratory with the performance of the soil in the field. This is not because the laboratory methods are wrong or inexact, but because the conditions obtaining in the field are very different and often undeterminable. The correlation between laboratory results and field results is gradually becoming more close, as the subject of soil study proceeds.

I. Chemical Analysis

The chemical analysis of soils aims to determine the kind and amount of plant-food ingredients contained in them. Simple as it seems, this problem is greatly complicated by the fact that these ingredients exist in soils in at least three categories of conditions. In soils being formed from rocks by the various processes included within the term "weathering," there is, first, the part as yet unaffected, or fresh; second, that which is fully or partially weathered; third, that which has been rendered water-soluble.

It is impossible for the chemist to imitate fully the action of plant-roots on soils, the more so as plants differ widely from one another in their ability to utilize the "reserve" or weathered part. Similarly, but to a much greater degree, do the solvents at the command of chemists differ in their solvent power. Even if we knew exactly the solvents used by plants, we could not put them into action in precisely the same manner. Soil analysis can, however, point out the great abundance, great scarcity or absence of each plant-food ingredient, and these indications can be quickly verified by cultural experience, past or present, thus vastly abridging the blind and costly experimenting that would otherwise be required. In other words, we are thus enabled to forecast with a great degree of probability the permanent cultural value of agricultural lands and their first needs in fertilization. Their immediate producing capacity is a wholly distinct problem, to be discussed later; the confounding of the two distinct objects is mainly responsible for a certain discredit which has been attached to chemical soil analysis. They can be simultaneously determined only in virgin lands; but until recently, soils long cultivated have alone served as subjects of investigation. Of the two, the permanent cultural value is evidently of the widest interest, since on it, other things being equal, land values are universally based. "Poor" lands, for which the minimum price only is paid, are those from which the weathering process cannot develop any important part of the plant-food supply needed for a crop, the whole having to be supplied annually by manuring; while "rich" lands are those which will continue in profitable production for a number of years without manure, and even subsequently require only the supplementing, by fertilization, of what is currently developed by the weathering process, aided by cultural treatment.

Analysis for permanent cultural value.

The discrepant results obtained because of the confusion of the two distinct objects of soil analysis, and its first application to the complex case of cultivated soils, have resulted in most unfortunate diversity in methods of analysis, which render the results of different observers in great part or wholly incomparable, owing to the differences in kind and strength of acids, time of extraction and temperature. Hydrochloric, nitric, oxalic, acetic and even sulfuric acids have been used, aside from the last resort, hydrofluoric; and different strengths of acid have been employed by the same person on different elements to be determined. It seems most difficult, if not hopeless, to secure unification in this respect, except by the adoption of some naturally limited procedure. Such a one has been adopted by the writer of this article, following the example of many distinguished investigators; the principle being to prolong the action of strong hydrochloric acid until it practically ceases to extract plant-food ingredients, leaving only the inert rock portion behind. The question is whether this process can be correlated to cultural results. It is believed that this can be, and has been done, and that conclusions thus gained with respect to virgin soils can be logically applied to cultivated lands also. The data given in this article are based on the analysis of a soil extract made by digesting the earth with hot hydrochloric acid of 1.115 density, for five days on the steam bath. The Association of Official Agricultural Chemists, while accepting the same strength of acid, has restricted the digestion period to ten hours, which in the writer's judgment is insufficient to serve practical purposes.

Interpretation of the results.—It must be understood that in all cases the proper physical conditions of the soil, as defined in the second part of this article, must be first considered. It is much more difficult to remedy physical than chemical defects, and the best chemical composition may be made useless by extreme physical defects, such as excessive clayeyness, lack of depth, and the like. This being understood, the following general statements may be made regarding chemical composition as ascertained by the above method:

(1) All virgin soils containing high percentages of potash, lime, phosphoric acid and nitrogen, are productive. To this rule no exception is thus far known, except in presence of extreme physical defects or of injurious substances.

(2) Very low plant-food percentages in general indicate low immediate and brief duration of productiveness. But great depth and permeability of soil may measurably compensate for this deficiency, provided the proportions between the several ingredients lie within certain limits.

(3) The presence of an adequate proportion of lime in the carbonate form is one of the prime factors to be considered in interpreting the practi-

cal import of a soil analysis. Its absence, usually manifested by the acid reaction on litmus paper, is a grave detriment in all cases; while in its presence even small amounts of other plant-foods will be found adequate.

The concrete meaning of the above maxims may be best shown by the examples given in the subjoined table, which at the same time shows the general composition of the acid soil extract, and the relatively small proportions in which the chiefly important mineral plant-food ingredients—potash, lime, phosphoric acid and magnesia—are present even in the best soils:

in the United States is characterized by such timber trees as black walnut, honey locust, linden, ash, black locust, also grape-vine and others. These plants are rightly held by farmers as characterizing "rich" soils. When the soils are clayey, it requires .4 to .6 per cent of lime to produce lime growth; in very sandy lands as little as .1 per cent of lime may produce such growth.

Potash fertilization seems, in field cultures, to become unnecessary when the potash percentage reaches or exceeds .45 per cent, provided a fair amount of lime be present. But in intense garden cultures the use of potash fertilizers may even

Chemical Analysis of Fine Earth	Rich Soils				Medium Soils				Poor Soils			
	Humid region		Arid region		Humid region		Arid region					
	Mississippi—Yazoo bottom, clay soil	Louisiana—Houma alluvial loam	California — San Joaquin, plains	California — Colorado desert, Palm valley, sandy soil	Mississippi—Table lands, brown loam	Mississippi — Oak and pine uplands, yellow loam	California — Riverside, reddish loam	Washington—Selah valley, gray loam	Florida — Pine woods, 2d class, sandy soil	Mississippi — Pine meadows, whitish sandy soil	Mississippi — Shell hammock, sandy soil	California — Red clay soil, "Bed-rock" land
Insoluble matter . . .	51.06	35.48	66.08	71.45	83.27	90.23	76.41	77.18	95.63	95.59	96.08	51.89
Soluble silica	20.70	20.76	3.38	5.50	5.56	2.32	8.20	4.51	.88			17.85
Potash (K_2O)	1.10	1.03	1.82	1.42	.37	.24	.87	.62	.12	.06	.05	.27
Soda (Na_2O)	.33	.13	.44	.18	.22	.09	.29	.24	.06	.05	.06	.16
Lime (CaO)	1.35	.72	4.31	2.20	.28	.09	1.57	1.32	.06	.02	.10	.11
Magnesia (MgO)	1.67	.88	1.56	2.09	.23	.20	1.33	.92	.04	.07	.12	.31
Manganese (Mn_3O_4) . .	.12	.01	.08	.05	.28	.07	.04	.05	.05	.05	.05	.03
Iron oxid (Fe_2O_3) . . .	5.82	7.10	6.04	6.68	2.39	1.84	4.20	5.62	.22	.46	.52	6.98
Alumina (Al_2O_3) . . .	10.54	15.45	8.69	5.78	4.51	1.86	5.30	5.24	.47	.85	.46	15.80
Phosphoric acid (P_2O_5)	.30	.15	.14	.35	.08	.09	.14	.13	.09	.05	.10	.04
Sulfuric trioxid (SO_3) .	.02	.25	.26	.01	.02	.01	.01	.09	.06	0.00	0.00	.03
Carbonic dioxid (CO_2) .	0.00	0.00	2.53	2.18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Water and organic matter	7.37	18.52	4.15	4.29	3.11	2.83	1.60	3.52	1.81	2.28	3.02	7.45
Total . .	100.38	100.48	99.48	102.18	100.32	99.87	99.96	99.44	99.49	99.48	100.56	100.92

It is here seen that the best and the poorest soils, such as the first three and the last four, differ very widely in their plant-food content; and their cultural values differ as widely, except that in the case of the last but one, a relatively higher ratio of lime, a depth of ten or twelve feet, and easy permeability to roots, redeem the apparent poverty of the soil to a material extent. The pine meadow and the Florida soil can be made to produce only by the use of manure. In the "medium" soils, the lime and potash content of the California and Washington soils greatly exceeds that of those from Mississippi; they represent differences which are found to exist between the soils of the humid and the arid regions in general, outside of limestone regions. Practically all soils of arid regions are calcareous, and are not benefitted by liming; while liming, together with potash fertilization, is among the most important improvements to be made in the humid region.

Fertilizer requirements.

Calcareous lands in the regions of summer rains may be recognized by their "lime growth," which

then be required, because the weathering agencies cannot then make available sufficient potash for a season's needs, even from a "rich" soil.

Phosphoric acid is universally considered as deficient when a soil contains less than .05 per cent; phosphate fertilization is then currently required. One-tenth per cent is satisfactory, .2 per cent and over is unusual. But this must be understood to be true only when soils do not contain unusual amounts of finely divided ferric hydrate, for the latter, especially in humid climates, may render even several per cent of phosphoric acid unavailable; and the same will occur to superphosphate fertilizers in the course of a season. Such fertilizers as bone meal or basic slag are then preferable. In the temperate humid region, the formation of bog ore or "black gravel" in the subsoil always indicates a surface soil depleted of phosphoric acid by maceration with water, or "swamping" of the land.

A large proportion of magnesia, especially when it exceeds that of the lime, is injurious to most crops, and renders liming advisable. Strongly magnesian soils, even when well supplied with plant-food, will otherwise lack thriftiness.

Nitrogen, one of the primarily important plant-food ingredients, is not determined in the general analysis, but by separate processes. It exists in the soil mainly in connection with the vegetable matter, which usually is only partly humified. The nitrogen contained in the unhumified vegetable part being practically unavailable to plants, the determination of the "total nitrogen" of the soil by combustion gives little clue to the adequacy of this element in the soil. It is therefore necessary to determine, separately, the nitrogen contained in the true humus, and, therefore, to determine the amount of the latter itself. This is done by the "Grandeau" process; viz., the extraction of the lime and magnesia of the soil with weak acid; then, after washing, extracting with weak ammonia water. The latter dissolves the humus, which can then be determined by evaporation. The black, shiny substance thus obtained contains, beside ash, a variable amount of nitrogen, from less than 2 per cent to over 20 per cent; hence its nitrogen must be directly determined in every case. The humus proper usually constitutes 40 to 60 per cent of the total organic matter of the soil.

Humus in soils.

In good soils of the humid regions, humus is usually present to the extent of .75 to 2.50 per cent, and even 10 per cent; in "sour" or peaty lands it rises to 20 per cent and more. Peat sometimes contains over 2 per cent of nitrogen, though this is unavailable to culture plants until the acid is neutralized by liming. It is only in non-acid humus that the nitrification which mediates the assimilation of soil nitrogen by plants can take place. In arid soils, humus is usually present in small amounts only; but while the humus of humid soils rarely contains over 5 per cent of nitrogen, that of the arid humus ranges from 12 to over 20 per cent; hence, a much smaller amount suffices for the needs of vegetation and sometimes as little as one-fourth of 1 per cent is found sufficient for immediate needs. Experience seems to show that when the nitrogen percentage in the soil humus proper is either naturally 2.5 per cent or less, or has been reduced by cultivation to that amount, nitrogen-fertilization is necessary; doubtless because nitrification cannot then proceed with sufficient rapidity. It is thus impossible to state what is an adequate total nitrogen percentage in a soil; all depends on its condition. It is generally stated that in normal, non-acid soils, .1 to .2 per cent of total nitrogen is adequate; and this seems to hold fairly good for calcareous lands.

The non-humified vegetable matter of the soil is of service both in improving the physical properties of the soil and in supplying food for the soil bacteria, whose action is of vital importance.

Soils of the arid and humid regions.

Extended comparisons have verified the fact, easily foreseen from the nature of the case, that in the regions of abundant summer rainfall the soil ingredients most readily soluble in the soil water, are very largely leached out into the country drainage, while in the regions of deficient rainfall these same ingredients necessarily accumulate in the soils. There is thus brought about a constant and intrinsic difference between the soils of the temperate and tropical humid, and those of the arid belts of the globe, which may be briefly summarized to the effect that in comparing soils of both regions not directly connected with limestone formations, we find in the arid, on the average, ten to fourteen times as much lime, three to four times as much potash, and five to seven times as much magnesia, as in humid soils; also, that, owing to the great depth, perviousness and uniformity of arid soils, due to the slowness of clay formation, water, air and plant-roots can penetrate the latter to much greater depths than is usually the case in humid soils, which generally have clayey, dense subsoils. Hence follows the smallness of the land-unit that in irrigated lands in arid climates suffices for the support of a family; hence, also, the higher prices that cultivators can afford to pay for such lands.

Arid soils in regions of extremely deficient rainfall retain, besides the above nearly insoluble ingredients, all the soluble salts that would otherwise have been washed into the country drainage and the sea. We then have "alkali lands" which, while extremely rich in plant-food, require reclamation before being fitted for ordinary crops.

Tropical soils are the extreme opposite of the alkali soils. They are thoroughly leached; but the rapid weathering under the constant stimulus of heat and moisture renders adequate much smaller plant-food percentages (possibly half) than would suffice in the temperate humid region.

It will be seen that in leading to an understanding of the points enumerated above, chemical soil analysis has rendered most important services to agriculture.

Ascertainment of the immediate producing capacity of soils, and of their needs in fertilization.

The question of immediate producing capacity —the "Düngezustand" and "Düngerbedürfniss" of the Germans—has formed the subject of many investigations, the results of which have not, however, led to universally satisfactory conclusions. It seems evident that in this case, as well as in that of the more incisive agricultural analysis considered above, regard must be had to differences in soils and climatic conditions.

In England, Dyer found that extraction of the soils with a 1 per cent solution of citric acid for twenty-four hours gave results approaching very closely those obtained in the cropping of the manured and unmanured fields of Rothamsted. This presupposes that the soils have first been made neutral, so as not to weaken the acid solution by the dissolution of lime and magnesia carbonates. He found that under these conditions, .005 per cent of potash and .01 per cent of phosphoric acid proved barely adequate for satisfactory crop-production.

W. Maxwell, and also the writer, found that in the case of the highly ferruginous (iron-bearing) soils produced from the Hawaiian lavas, the citric acid solution was wholly unsatisfactory as regards phosphoric acid, of which it dissolves a large amount, while phosphate fertilization is eminently effective in sugar-cane production on these soils. He found that for the Hawaiian soils a solution of aspartic acid extracts in twenty-four hours almost the exact amounts and proportions of plant-food as do the crops. This process has not been sufficiently tested elsewhere, on different soils, but deserves much attention.

Professor F. H. King finds that, when soils of different degrees of productiveness are subjected to protracted leaching with pure water, there is a continuous extraction of plant-food ingredients very strikingly proportional to the actual productive capacity of the land; and then, when the soil is subjected to alternate leaching and hot-drying (as is always more or less the case in the fields), the amounts so extractable are quite adequate for the nutrition of the crops produced. In this case, also, "rich" soils yield much larger amounts (one and one-half to eight times as much) of the important plant-foods than the "poor" ones. If this relation is verified by further experiments, it offers the simplest means of determining the immediate productive value of soils, while also affording some clue to their permanent value.

Finally, there is the direct test on vegetation plots fertilized with the several ingredients, singly as well as in combination with one another; there should be not fewer than six such plots, with at least four blanks interspersed. This looks like the most direct and conclusive test, and in competent hands and under normal conditions it will be so very often. But seasonal differences, local diversity of soils, accidents and especially failure of the farmer to observe the rigorous precautions required for success, render this a much less available procedure than it appears to be. Experienced experimenters in Europe state that it takes about seven years to come to perfectly definite conclusions regarding the needs of cultivated land by means of plot-cultures. Well-controlled pot-cultures are much more conclusive, but cannot well be made by the farmer.

It would thus seem that physico-chemical soil analysis, judiciously interpreted, is the quickest mode of obtaining definite information regarding the permanent value of soils, and can probably serve for the immediate producing capacity also.

Literature.

On methods of chemical soil analysis little has been published in this country aside from Wiley's Principles and Practice of Agricultural Analysis and the reports of the Association of Official Agricultural Chemists. Early papers were written by David Dale Owen in the First Report of the Geological Survey of Kentucky, and articles by S. W. Johnson (September, 1861) and E. W. Hilgard (December, 1872) in the American Journal of Science. A summary of Hilgard's methods has been issued as Circular No. 6 by the California Experiment Station, and full discussions of chemical soil analysis are given in Chapters XVIII and XIX of the book on "Soils" by the same author.

II. Physical or Mechanical Soil Analysis

The physical analysis of soils has for its object the definite ascertainment of the constitution of the soil in respect to its physical composition, which governs its tilling qualities, relation to water, air and the penetration of roots. The physical components of soils are, in general terms, mineral powders (silts and sands) of various grades of fineness, with more or less of plastic clay and nearly always some humus. The separation and quantitative estimation of the two former is the task of physical soil analysis. [Another discussion of mechanical analysis will be found on page 351, by Professor Stevenson.]

Without proceeding to this, however, a fair idea of the tilling quality of a soil may be gained by the "hand test," as follows:

First, a small lump of the dry soil is taken between the forefinger and the thumb, and it is observed whether or not it crushes easily; this will give a useful hint as to how the soil will act in plowing and harrowing. Next, a similar small lump is placed in the palm of the hand and on it a few drops of water are poured; it is then observed whether the water is absorbed quickly or slowly. This will indicate how the soil will receive rain or irrigation water. Now the wet lump is kneaded with the thumb and finger until it attains its greatest plasticity ("stickiness"); this will indicate the content of clay, and the action of the land when plowed wet. The presence or absence of coarse sand or gravel, and the nature of the gravel if present, can also thus be observed. These simple manipulations, skilfully carried out, will often render superfluous any more elaborate physical analysis. But, if the latter is to be made, the first operation must be the separation of the clay.

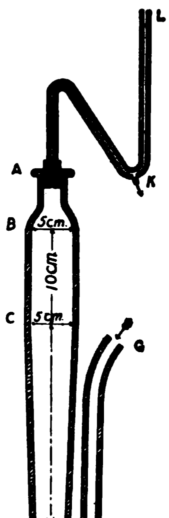


Fig. 479. Schöne's elutriator used in soil analysis.

Separation of the clay.

Clay is distinguished from the powdery components by its adhesive plasticity, by virtue of which the soil is made more compact and its particles held together in crumb form even when dry. Clay particles are so extremely fine that when a soil or natural clay is stirred up in pure water they will remain suspended or diffused for weeks and even months, rendering the water turbid. By means of this property the true clay can be separated from the powdery particles, provided it has first been detached from the silt and sand grains. This can be done either by kneading the wet soil in the hand, by gently rubbing it in a mortar with a rubber pestle, by boiling it with water for some hours, or by a thorough shaking with water in a shaker apparatus. After the addition of more water, the sand and powdery portions are either allowed to settle down from the clay water (usually from a column not exceeding 8 inches in height) for 24 hours or more, or else the mixture may be placed in bottles mounted in a centrifuge (Fig. 473), whereby the separation is made much more rapidly. In either case, the operation has to be repeated until the sediments when stirred up with water do not render it permanently turbid.

The omission of this separation of the clay from the powdery portion has rendered the early work on this subject (with Nöbel's apparatus) very inaccurate and erroneous, since the clay causes the formation of flocculent crumbs, thickens the water and prevents the accurate separation of the powders.

The clay can be determined by evaporating a measured quantity of the clay water to dryness and weighing; or it may be thrown down as a gelatinous mass by the addition of salt, or of lime water. On drying, it then forms horny scales, which on moistening with water swell up enormously, and become very adhesive and plastic.

Separation of the silts and sands.

After the removal of the clay, the powdery silts and the sands can be separated into as many sizes as may be desired, by several means. The simplest is a series of sieves, used by the Bureau of Soils of the United States Department of Agriculture, the finest being of silk bolting cloth. Sifting, however, does not admit of as close discrimination of the smaller sizes as is necessary for some purposes; hence, such separation is mostly made

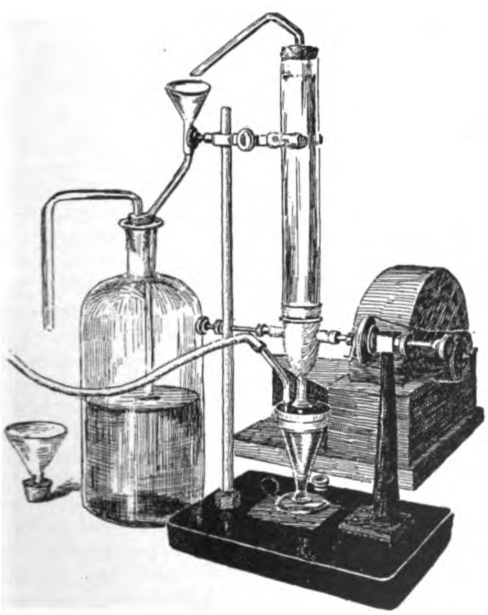


Fig. 480. Hilgard's churn elutriator.

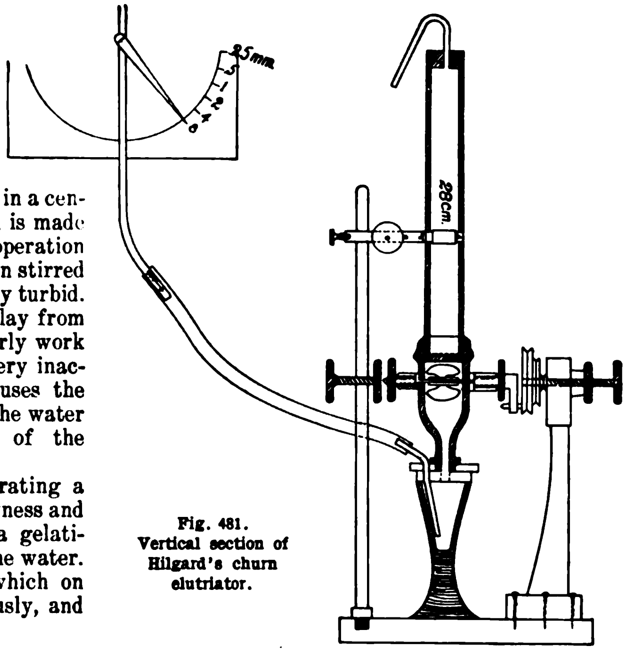


Fig. 481. Vertical section of Hilgard's churn elutriator.

either by means of timed subsidence from water columns of measured height, or else by the use of ascending currents of water of definitely varied velocity. By either method, the separation of the several grain sizes may be carried to any degree of subdivision that is desired.

The subsidence method.—In the subsidence method, long practiced in the arts and lately renamed the "beaker" method, the powdery sediments are suspended in distilled water in a cylindrical, or preferably somewhat conical glass vessel, of which a great many different forms have been invented. After stirring in such a manner as not to give rotary motion to the water, the operator times the subsidence periods selected, by means of a second-hand watch. At the end of each period, the fluid above the material that has gone to the bottom of the vessel is rapidly drawn off into a settling vessel by means of a siphon with an up-bent inlet. The operation is then repeated until at the end of the same interval the water remains clear, when all the sediment corresponding to that time interval can be collected in the second vessel. A selected shorter interval is then used in working off the next coarser sediment desired; and so on, until the residue remaining is so coarse as to be readily treated by sifting. It will be noted that this method has the advantage of requiring no elaborate apparatus; but it does require the entire time and patience of a reliable operator, and only one soil can be handled at once.

Hydraulic elutriation.—The method employing an ascending water current to carry off the several sediments consecutively can be made to work automatically and with several samples at once, taking but little of the time of the operator. The simplest arrangement of all is a short, cylindrical glass vessel or beaker, in the bottom of which the prepared earth sample is placed and stirred with a little water. A water current that can be regulated by a faucet is then passed in through a tube terminating near the middle of the bottom; and by placing the cylinder in a receiving basin the operator can make as complete a separation as he pleases and collect and measure or weigh the several sediments. For most practical purposes this is a very satisfactory and sufficient procedure.

For more accurate determinations, several instruments have been devised. The oldest is the apparatus of Schöne (Fig. 479). It consists of a conical tube, becoming cylindrical at its upper end, and terminating below in an inlet-tube curving upward, through which a regulatable water current enters, stirring up the prepared soil placed in the bend of the tube, and carrying off such portions of it as are borne up the water at definite velocities, the sediments being then collected by subsidence and weighed after drying.

The objection to this instrument is that in consequence of the conical form of the washing-tube, return currents are formed down the sides, causing the fine grains to form complex heavy crumbs or floccules, which fail to pass off at the current-velocity to which the individual particles correspond, the agitation caused by the current alone being unable to resolve them into single grains. This can be partly obviated by using a cylindrical washing-tube; but it is then difficult to keep the soil mass properly stirred and acted upon by the water current.

Fig. 482. Showing the several sediments into which soils have been resolved. The uppermost tier represents a heavy but workable clay soil; the lowest, a very sandy and pervious soil; the middle tier, a medium loam.

All these difficulties are avoided by the "churn elutriator" devised by Hilgard (Figs. 480, 481), in which a cylindrical tube about 40 mm. (1.6 inches) wide has at its base a horizontally revolving stirrer driven by a motor, the action of which wholly prevents the formation of the aggregates or floccules. The churn compartment is separated from the main tube by a wire screen, to prevent irregular agitation of the water column; below it is a conical "relay" glass, communicating with the churn above by means of a tube 10 mm. wide, through which the sediments concerned in any given velocity pass up into the churn, while the coarse portions remain in the relay glass and are not unnecessarily made to abrade each other. When their turn comes, they can quickly be made to pass into the churn and elutriator-tube by a rush of water, the current being afterwards quickly moderated to the desired velocity. This instrument works automatically and takes the time of an operator only when a change of velocity is called for. The tall receiving-bottle shown in the figure prevents any loss automatically, the sediments accumulating at its bottom.

A "centrifugal elutriator" combining hydraulic elutriation with centrifugal subsidence, has been constructed by Yoder, but is too complex to be briefly described.

In Fig. 482 are shown the several sediments into which soils have been resolved, arranged in vials of even diameter, and thus at once indicating, by the curve formed by the surfaces, the physical character of the soil. The uppermost tier represents a rather heavy but yet workable clay soil;

the lowest a very sandy and pervious soil; while the middle figure represents a medium loam, such as is deposited in river bottoms.

Summary of the interpretation of physical analyses.

Plastic clay being the governing factor in texture of soils, attention must be given to its amount, and then to modification of its properties by the several powdery sediments or their combinations.

(1) Coarse sand larger than ½ mm. ($\frac{1}{50}$ inch) detracts but little from the extreme adhesiveness and plasticity of clay. Hence the attempt sometimes made to improve heavy clay soils by the admixture of mere coarse sand alone naturally fails.

(2) On the other hand, a large proportion of very fine powdery sediment produces a closeness of texture that makes the land difficult to till, it being pasty when wet and forming a hard "cement" when dry, so that it can be tilled only between narrow limits of moisture condition. Soils consisting of fine powdery grains with only a small percentage of clay resemble putty in physical properties, and are known as "putty soils," which adhere to the plowshare, and dry to stony hardness.

(3) The soils that most readily assume a condition of loose flocculation and resulting good tilth are those containing, with 5 to 15 per cent of true clay, "assorted sizes" of silt and sand between the diameters of .5 and .025 mm. ($\frac{1}{50}$ to $\frac{1}{1000}$ inch), without a large excess of any one sediment. These are the "loams" desired by the farmer, light or heavy in tillage according as the proportions of clay and finest grain-sizes are large or small.

It is not yet possible to construct a definite formula by which the resistance offered by a soil in plowing, or its precise behavior toward water, can be calculated from the physical analysis; this must for the present remain a matter of estimate and judgment. Several elements of uncertainty enter into the problem, such as the presence of more or less humus, lime, iron oxid, the individual character of the clay substance, and the form of the powdery particles. When clay contains a relatively large proportion of lime its adhesiveness is greatly diminished, and it tends on drying after wetting to crumble into loose tilth, as occurs in the black prairies and in the Yazoo clay lands. In such cases even 40 per cent and more of clay may be present without injury to tilth. On the other hand, there are sands in which the grains are flat or wedge-shaped, and which on wetting pack into an almost impervious "hard-pan," the more so the less clay is present. Such soils are intractable.

These and many other conditions combine to render the results of accurate physical soil analysis less directly applicable to farm practice than could be desired, but further investigation will bring it into closer and more direct relation.

Literature.

Most of the American writings on this subject are summarized and discussed in H. W. Wiley's work on Agricultural Analysis, Vol. I. Aside from this book, the only separate publications issued on the subject are the Reports of the Proceedings of the Association of Official Agricultural Chemists, issued by the Department of Agriculture at Washington. Earlier discussions of physical analysis may be found in the Proceedings of the Portland meeting of the American Association for the Advancement of Science and in the American Journal of Science, October and November, 1873, by E. W. Hilgard and R. H. Loughridge; later discussions in the Report of the Connecticut Experiment Station, 1886, by T. H. Osborne; Bulletin No. 89 of the Utah Experiment Station, by P. A. Yoder; Bulletin No. 24 of the United States Bureau of Soils, by Milton Whitney; Chapter VI of the work on "Soils," lately published by E. W. Hilgard.

THE CHEMISTRY OF THE SOIL-SOLUTION

By *Frank K. Cameron*

The mineral debris forming the soil has become much mixed in the process of formation. It rarely rests on the parent rock, but has been transported from its original location and after various admixtures has been deposited on foreign terrane with which it has had no previous connection. Many of the parent rocks of now-existing soils have themselves in their turn been soils derived from still older rocks, been deposited as sediments, compacted, elevated, again disintegrated and decomposed into soils. In consequence, practically all the common rock-forming minerals are to be found in any arable soil, although the relative amounts may vary rather widely from those in the rocks from which the soil was formed. [For a full discussion of soil formation, see Mr. Merrill's article on page 324; and for an editorial paragraph on the soil-solution, see page 321.]

The soil-solution.

The minerals in the soil are all more or less soluble in water. It is a matter of common knowledge that streams, wells, springs, which may be regarded as more or less diluted soil extracts, usually contain dissolved mineral matter. With larger crystals the rate of solubility is so slow that we have become accustomed to think of the substances as practically insoluble, but, if the amount of surface exposed to the action of the water be greatly increased, as by powdering the mineral,—a condition approximating that in the soil,—appreciable quantities of all the common rock-forming minerals will readily pass into solution. The water acts not only as a solvent but also as a chemical reagent with such minerals as the silicates, alumino- and ferro-silicates of the alkalis and alkali earths. These minerals may be regarded as salts of weak acids, and, like such salts, are readily decomposed by water, or hydrolyzed.

With accumulation of the products of hydrolysis in the soil-solution, the solvent reaction will tend to an end; that is, there will be an equilibrium between the solid mineral and the dissolved and hydrolyzed products of the mineral. As the dissolved base is removed from time to time either by being leached away or by being absorbed into growing plants, a further solution and hydrolysis of the mineral will take place so that there will be always a tendency toward a definite concentration in the soil-solution. Since all soils contain practically the same minerals, it might be expected that the soil-solution would be essentially the same in all soils if other disturbing factors did not enter.

Factors influencing the soil-solution.

Among the disturbing causes which affect the concentration and character of the soil-solution, an important one is the bacterial flora present in all arable soils. The concentration of the soil-solution with respect to nitrates varies more widely perhaps than toward any other mineral substance, owing to the rapidity of action of nitrifying or denitrifying organisms, depending on the atmospheric conditions in the soil. Changes produced by temperature are probably important. So far as is known, increase of temperature increases hydrolysis (or decomposition by water), and it is probable that any increase in temperature in the soil would increase the extent to which the soil moisture would react with the mineral components. Synthetic processes, however, are undoubtedly taking place within the soil as well as destructive ones, and an increase in concentration with respect to any one or more bases might induce a formation of mineral species tending to maintain a normal concentration in the soil-solution. The addition of inorganic salts to the soil affects the concentration of the soil-solution, in general, in accordance with the indications of the dissociation hypothesis; that is to say, salts that yield a common ion decrease the solubility, while salts that yield an uncommon ion tend to increase the solubility. The influence of dissolved organic matter on the solubility is probably great, but as yet is little understood. For a long time it was assumed,—on evidence which, according to modern standards, is entirely inadequate and inconclusive,—that certain groups of so-called humic acids exist, which exert a powerful solvent action on the minerals. It is much more probable that the chemical influence of the organic material is an indirect rather than a direct one, and is produced through absorption and surface effects, as will be pointed out presently. Dissolved gases undoubtedly play, in the aggregate, an important part in the solution of the mineral matter in the soil. By far the most important is carbon dioxid, which by forming bicarbonates with bases decreases the active mass of the hydroxid in solution and thus tends to increase solubility. Rain-water falling through the air absorbs relatively much more oxygen than nitrogen, and after entering the soil much of this oxygen again escapes, producing marked effects, not only on the organic matter in the soil but on the minerals, especially those containing ferrous iron as an essential constituent. Other gases, such as sulfur dioxid, oxids of nitrogen, ammonia, and so forth, are dissolved from the air in minute amounts, but in sufficient quantity when carried into the soil and concentrated by absorption to have an appreciable influence on the solubility of the minerals.

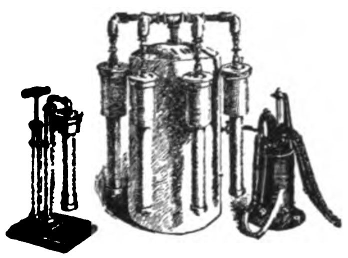


Fig. 483. Pressure-tubes used in obtaining soil extracts. The water is forced through soil in the apparatus.

Aside from the bacterial flora, there are other organic agencies in the soil affecting the solubility and metamorphisms in the soil minerals. Molds, fungi, and probably enzymes, are all more or less active in modifying the soil-solution. Earthworms, crawfish, and many other organisms are found working through the soil, stirring it up mechanically and sometimes profoundly modifying it chemically, as in the casts of earthworms. The roots, undoubtedly, have considerable chemical effect on the mineral as well as organic composition of the soil-solution, as, for instance, the recently demonstrated fact that there is a very active oxidation at the surface of the roots of many plants.

Movement from subsoil.

The concentration of the soil-solution with regard to mineral matter is somewhat greater than would be expected from the known solubility of the minerals composing the soil. The explanation, however, is obvious. There are in the soil two general movements of the water or soil-solution. When water is brought on the surface of the soil, part of it runs off and part enters the soil itself. This latter penetrates the soil comparatively rapidly under the influence of gravity, and passes through the larger channels or spaces until it finds its way into an underdrainage system, or into a part of the soil containing less than enough water to saturate it. With subsequent evaporation at or near the surface, a contrary and upward movement of the water takes place through the capillary spaces and in films over the soil grains, which is slow as compared with the downward movement of the gravitational water. This capillary water, if we may term it such, in its ascent takes up and dissolves from the soil much mineral matter, but the gravitational water in its descent through the soil takes comparatively little—first, because it comes in contact with much less surface of the soil and for a less time than the capillary water, and secondly, because the diffusion of the dissolved mineral matter from the capillary water is very slow. In consequence there is a steady tendency toward an accumulation of dissolved mineral matter at the surface. In this sense, therefore, we may regard plants as being constantly supplied with mineral nutrients from the subsoil below that which the roots ever reach.

Absorption by soils.

Another factor affecting the concentration of the soil-solution is the absorptive power of the soil. This power is exhibited toward gases and toward dissolved organic and inorganic matter in the most remarkable way, and may be due to a purely surface effect which is known as "adsorption," to chemical reactions, occlusions, and so forth. So far as investigations have yet gone, the total absorption, no matter to what it may be due, follows a law analogous to the simplest possible kind of chemical reaction, and the rate of absorption is also analogous to the rate of such a reaction.

In the converse process of leaching absorbed mineral substances from the soil, the first leachings may have rather high concentration, but this very quickly falls with successive leachings, which continue to diminish so gradually as to be practically constant under all ordinary conditions even though the amount of absorbed material remaining in the soil may be relatively very great. Moreover, laboratory experiments have shown that the concentration of these soil-percolates from widely different soils vary within rather narrow limits. Soils do show marked difference, however, in the avidity with which they absorb different substances from solutions. This can be well illustrated by passing through a short column of soil, a solution of a mixture of the strongly colored dyes eosine and methylene blue. The first runnings of the percolate will be colorless pure water, then gradually the red eosine will be observed in the percolate, but a relatively enormous amount of solution must be passed before the percolates will show any trace of the blue dye. In a similar way, partial separations can be effected of the organic substances in manures, and this "selective" power of absorption is obviously a most important property of the soils. But not only do soils show a selective power in separating one subtance from another, but they actually separate one constituent of a salt from another. For instance, if a neutral solution of potassium chlorid be passed through a soil column, the percolate always contains some free acid.

It is well known that these absorption effects are a function of the amount of surface exposed to the solution containing the substance which is being absorbed. It is therefore to be expected that soils which possess enormous surface, compared with the mass, would show these effects in a very pronounced way; and it is further evident that the reactions which one might expect by introducing the reagent into a beaker would be quite different from that which takes place in the soil where part of the reagent was absorbed and to a greater extent than another part. It is the failure to recognize this fact which has brought much confusion in the past and seriously retarded this important branch of applied chemistry.

Intimately associated with this subject is the influence of absorbed material on the physical condition of the soil. Certain substances have a flocculating action, that is, cause the soil grains to aggregate themselves together, leaving the soil in a more porous condition. Other substances have quite the contrary effect, and the amount of reagent or added substance necessary to produce a marked degree, either in flocculation or deflocculation of the soil, is frequently very small, indeed so small as to preclude the idea that the mechanism of the phenomenon is to be explained as an ordinary chemical reaction.

Organic substances in the soil-solution.

Unlike the mineral constituents, it is reasonably certain that the same kinds of organic components are not present in all soils. They may be the direct excreta of the roots of higher plants, the resultant products of bacterial activities, or of other origins. No generality is yet justifiable as to their concentrations, which may vary rather widely, although it seems probable that the more effective ones are usually present in the solution in minute amounts. They can generally be very readily removed from solution by good absorbent agents such as carbon black, ferric hydrate and others; and their action on plants is often much modified by the addition of salts or even other organic substances, although there is as yet no positive evidence that this is not a physiological phenomenon involving the mechanism of absorption by the plant rather than merely a chemical or physical phenomenon in the soil-solution itself.

Fertilizers.

Long experience has justified the use of certain organic materials and inorganic salts as manures or fertilizers. It has been supposed generally that these substances are useful as supplying an increased amount of mineral plant-food constituents, although secondary effects, as on the physical condition of the soil, are universally admitted. It is well known that the particular fertilizer that will produce the best effect on any given soil with any given crop is determined by the season, climate and past cultural history as much as or more than by any chemical characteristics which existing methods can determine. Just as great effects can be produced in many cases, and of the same kind, by the addition of substances containing no mineral constituents, or by the removal of substances in the soil-solution, as by the addition of any one or more of the usual fertilizers. There is accumulating evidence that the fertilizer needs of a region are determined by the agricultural practices, climatic and physiographic conditions, rather than by the chemical or physical characteristics of the soils or soil types. These facts are most readily explained by the views developed above; it would seem that, in general, the principal function of fertilizers is to affect the organic substances in such a way that they are harmless, to induce conditions under which harmful organic substances are made innocuous through bacterial or other agencies, or so to affect the growing plant physiologically that it can withstand harmful organic substances that are contained in the soil water.

Literature.

For a fuller development of these ideas, the reader is referred to the recent bulletins of the Bureau of Soils, United States Department of Agriculture, and the references there cited.

CHAPTER XI

TREATMENT OF SOIL BY MEANS OF TILLAGE

THE TILLING OF THE LAND HAS A HISTORY. We consider every natural object, every human institution, and every opinion in respect to its origin and evolution. This history is valuable not only because it affords us certain isolated or interesting facts, but because it enables us to discover the gradual unfolding of ideas, to correlate any movement with the time or epoch in which it occurred, and to forecast something of its trend or destiny. Yet few persons, perhaps, have thought of the tillage of the ground as having a history. Tillage is so universal and so obviously essential to successful agriculture, that we accept it without questioning its origin. If we take even the most cursory glance at the methods of tilling the land and the reasons for it in past times, however, we shall acquire a greater appreciation of its importance and shall be better able to understand its full significance to the farmer; and it is not unlikely, also, that we shall discover that simple tillage has had very much to do with the amelioration of the vegetable kingdom.

Stirring or turning the land rests on two motives,—first, to facilitate the operations of planting and harvesting; second, to improve the condition of the soil, and consequently improve the crop. The first stirring of the land was undoubtedly practiced solely for the purpose of enabling the husbandman to get the seed or plants into the soil, and, in the case of root crops, to get the product out of it. The first tillage implements of which we have any knowledge seem to have been devised for the former use. They were hand tools, with the general features of a hoe. Later on, these implements were dragged behind the operator, instead of being wielded in front of him. Probably this idea developed the plow, an implement that was first drawn or pushed by men. The next step in the manipulation of the land appears to have arisen from the necessity of destroying intruding plants or weeds. These intruders came into the fields as fast as any land was broken or unoccupied, and a sharp struggle for existence at once ensued. In time, implements were developed for the express purpose of combatting weeds.

The agriculture of Greece and Rome appears to have rested largely on this negative theory of soil manipulation,—that the working of the land is a necessary burden imposed on the husbandman because of the intractable soil and the incursions of weeds, a notion that many of us inherit. There appears to have been little definite knowledge of the fact that manipulating the soil may render it more productive, although thorough preparation of it is advised by Pliny and others. Columella, and other writers, declare that the soil must lie idle for a time, at intervals, in order that it may recuperate or regain its strength.

The ancients do not seem to have looked on the loss of fertility in cropped lands as a proper depletion of the soil so much as an evidence that the soils contained superfluous or redundant strength in the beginning. "It is true," says Columella, "that the ground, after it has been brought into cultivation, seems to fall back in the scale of fertility; but the fruitfulness which it first possessed was owing to its having been fattened, as it were, by the residue from so many former crops which it had spontaneously brought forth." The Romans had learned the value of fertilizers, particularly of dung and ashes, and it was a practice, according to Vergil, to burn off the ground in order to increase its fertility. Green-manuring was well known. Among other practices, for example, Pliny quotes Cato as saying "that there are some crops which tend to nourish the earth: thus, for instance, corn land is manured by the lupine, the bean, and the vetch." The chief reliance, however, appeared to be put on fallowing or "resting" of the land, and on "change of seed" or rotation of crops. Vergil may well be consulted on Roman practices, as his account is specific.

> "But sweet vicissitudes of rest and toil
> Make easy labor, and renew the soil.
> Yet sprinkle sordid ashes all around,
> And load with fatt'ning dung thy fallow ground."

In the spring, Vergil advises that the rich land be plowed,

> . . . . "and let it open lie
> Till dusty summer have baked it through and through
> With his ripe suns."

The stubborn land should be plowed in the fall. The poorer lands should lie idle every other year:

> "But on the alternate seasons hold thine arm
> And the field newly gathered assail thou not.
> Suffer it rather for so long to lie
> Fallow and thirsty, under the parching sky."

This system of fallow farming was beset with difficulties, for the unoccupied land is not only unprofitable, but it invites a horde of weeds; and the monotonous recurrence of the same crops encourages insects and diseases. The poet is free to confess the discouragements. In the early days, he tells us, before the fields were parceled off, the earth satisfied the needs of all. "Now those old days are done," and Jove interposed countless ills on the husbandman. He gave poison to the serpent, "bade the wolf prey, and lifted the angry wave," and locked up the "running rivers of wine" in the "strait channels" of the vine.

> "Yet even upon the grain fell plagues erelong,
> Mildew defiled the stalks, and everywhere
> The barbéd thistles gathered in lawless throng,
> Till villainous weeds displaced the harvest there;
> Caltrops and cleavers, darnel, wild oats forlorn,
> Darkened the gracious glistening of the corn.
> Wield, therefore, a tireless rake against thy foe;
> Scare birds with din; pay vows to heaven for rain."

All this is not unlike complainings of the present day, and they arise from the same causes,—the misunderstanding or neglect of the few fundamental essentials of the cropping of the land. But Vergil was philosopher enough not to repine; there must be some object in the hardship which Jove has heaped on the farmer:

> "And all these things he did,
> That man himself, by pondering, might divine
> All mysteries, and, in due time, conceive
> The varying arts whereby we have leave to live."

"In due time!" It was not given to Vergil or his race to see the fulfilment of the prophecy. We are only now coming to understand and to apply the knowledge of the "mysteries" of the rural arts; and the greater number of our people have not yet apprehended the simple lessons of the tillage of the soil. The flight of years, with their promises yet unfulfilled, reminds us of that other prophecy of Vergil, who, amidst the devastating and professional wars of his age, perhaps meant to foretell the supplanting of the sword by the plow:

> "O long, long hence,
> In those far-marches, shall the laboring man
> Upturn the rusted javelin with his share,
> Smite with his fork the empty helm, or bare
> With awe the bones of the mighty to the air."

Out of the experience of the centuries, there slowly arose a belief that the soil is actually the better for being loosened and stirred. Many writers hinted at it. Vergil insists on good tillage, as shown in two renderings of a passage:

> "Much more advantage to the swain it yields
> To use the rake, than harrow sterile fields;
> Nor golden Ceres, from the lofty skies
> Shall view his labor with regardless eyes.
> And who, athwart the furrows, plows the plain,
> Then breaks the clods obliquely o'er again,
> Turning his team, and by a frequent toil,
> To obedience brings a disobedient soil."

> "And ruddy Ceres, from the Olympian top,
> Cheer him who smites the furrow's long exposure
> Crosswise again, with plow reversed, and wields,
> With keen intent, the sceptre of the fields."

Yet, all this refers to preparation of the land rather than to maintaining it in condition, and there is only the smallest record in ancient writings of the direct tillage of the crop for the crop's sake. What transpired in later and mediaeval times is little known to us, for the agricultural history of those times is not yet collected; but we know that in the south of Europe there was gradually established a system of tillage between the rows in the vineyards. This practice attracted the attention of an English landlord who traveled in southern France nearly two centuries ago, and it was transferred to various crops on his estate at home. This traveler was Jethro Tull, and the results of his studies and experiments were published in 1731 as the "New Horse-Houghing Husbandry."

Jethro Tull's purpose was to institute tillage as the means whereby soils may be constantly and forever reinvigorated or renewed. In order fully to understand his hypothesis, it is necessary to say that scholars were at that time divided as to where the plant secures its food, or, rather, what the plant is made of. The materials out of which the plant was supposed, by various persons, to draw its subsistence were niter (salt-peter), water, air, fire (or heat), and earth. Bradley, a professor in Oxford, had written a book in which he contended that air is the proper food of plants; but Tull at once ruled out "that acid Spirit of the Air, so much talk'd of; since by its eating asunder Iron Bars it appears too much of the nature of *Aqua Fortis*, to be a welcome Guest alone to the tender Vessels of the Roots of Plants." He concluded that earth is the "true food" of the plant. "Every Plant is earth, and the Growth and true Increase of a Plant is the Addition of more Earth." "Suppose Water, Air, and Heat, could be taken away, would it not remain to be a Plant, tho' a dead one? But suppose the Earth of it taken away, what would then become of the Plant? Mr. Bradley might look long enough after it before he found it in the Air." "Besides," he continues, "too much Nitre (or other Salts) corrodes a Plant; too much Water drowns it; too much Air dries the roots of it; too much Heat (or Fire) burns it; but too much Earth a Plant never can have unless it be therein wholly buried." "And Earth is so surely the Food of all Plants, that with the proper Share of the other Elements, which each species of Plants requires, I do not find but that any common Earth will nourish any Plant."

Having shown, to his satisfaction, that earth is the true and only food of plants, he must next discover how the plant takes it in. The soil is the "pasture of plants." This pasture, or source of food, is "the inner or (internal) Superficies of the Earth; or which is the same thing, 'tis the Superficies of the Pores, Cavities, or Interstices of the divided Parts of the Earth, which are of two sorts, viz. *Natural* and *Artificial*." Now, the plant takes its earth in this way: "The Mouths, or Lacteals, being situate, and opening, in the convex Superficies of Roots, they take their Pabulum, being fine Particles of Earth, from the Superficies of the Pores, or Cavities, wherein the Roots are included." "The internal Superficies, which is the natural Pasture of Plants, is like the external Superficies or Surface of the Earth, whereon is the Pasture of Cattle; in that it cannot be inlarg'd without Addition of more Surface taken from Land adjoining to it, by inlarging its Bounds or Limits." That is, the plant feeds and grows by taking in minute particles of earth; these particles are disengaged from the surfaces of the soil grains: it follows, therefore, that the more finely the soil is divided the more numerous the particles that will be disengaged and the more readily the plant will grow; and this is the foundation of Jethro Tull's philosophy. If all this is true, it follows that fertilizers are of value to the land only as they tend to comminute it. Tull ascribes the good results that follow the use of manures to the dissolving and crumbling action that they have on the soil, for manure "divides the Earth very much: This is the chief, and almost only Use of Dung." If the stirring and grinding of the land is continuous, the greatest number of particles of earth will be placed at the disposal of the roots; and "there's no Doubt," he says, "but that one-third Part of the Nourishment raised by Dung and Tillage, given to Plants or Corn at many proper Seasons, and apportion'd to the different Times of their Exigencies, will be of more Benefit to a Crop, than the Whole apply'd, as it commonly is, only at the time of Sowing." Tull also noticed that tillage renders the ground moist, although he thought that this moisture was procured from the dews.

How the "prolific particles" are separated from the soil grains was a subject of speculation with Tull. He doubted whether they fall away "by their own Gravity." He thought it possible that "the Nitre of the Air" is the active agent. But, whatever the mode or agency, it was clear that it is the part of the husbandman to "divide the soil"; and the methods of dividing it are adding dung and employing tillage.

Tull advised that wheat, oats and other crops be planted in drills to admit of tillage with a horse-hoe, and he devised a number of interesting tools to perform the labor. He gave much attention to plows. "'Tis strange," he says, "that no Author should have written fully of the Fabric of Ploughs! Men of the greatest Learning have spent their Time in contriving Instruments to measure the immense Distance of the

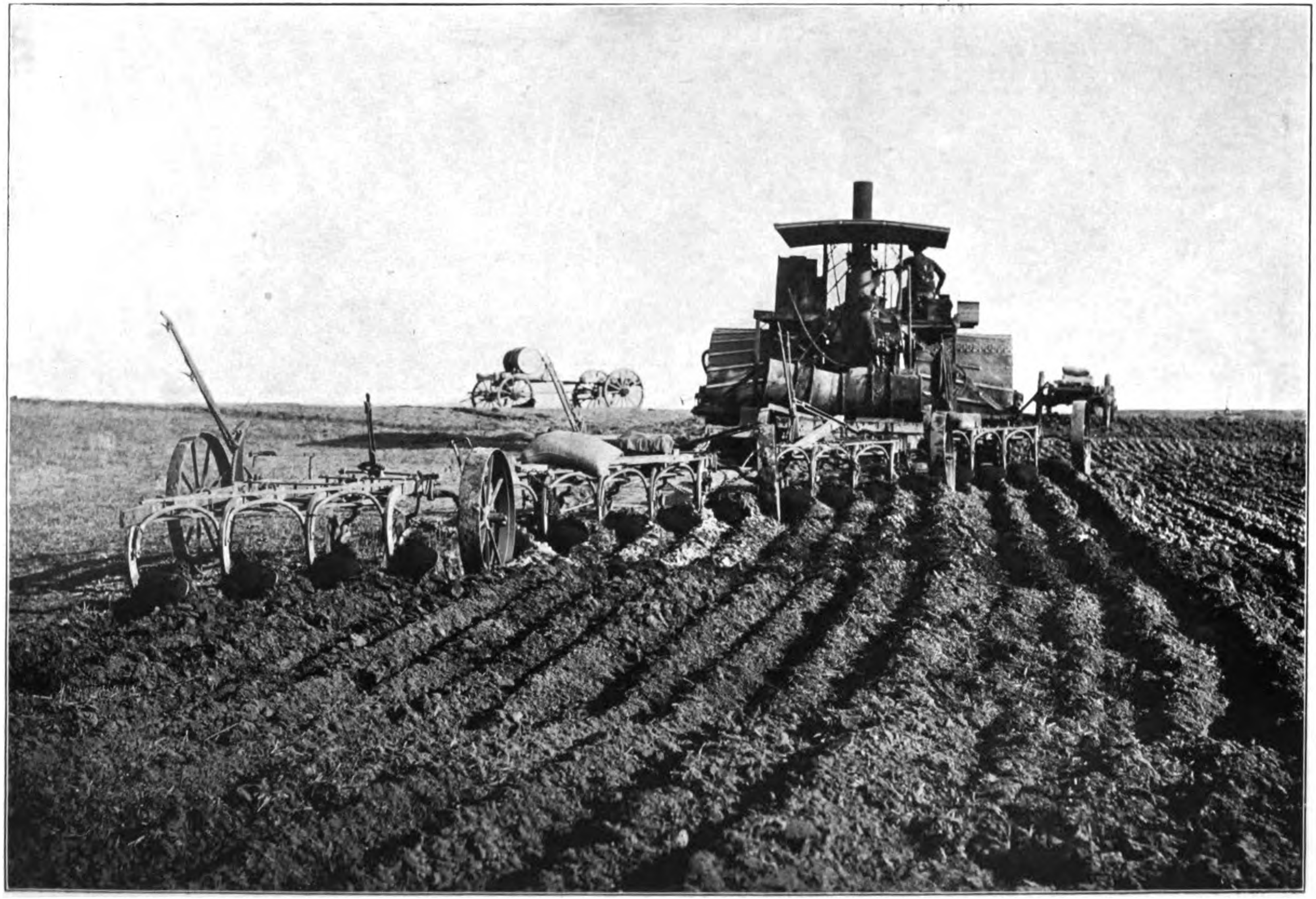


Plate XX. Plowing for wheat by means of steam power. California

Stars, and in finding out the Dimensions, and even Weight of the Planets: They think it more eligible to study the Art of plowing the Sea with Ships, than of tilling the Land with Ploughs; they bestow the utmost of their Skill, learnedly, to prevent the natural Use of all the Elements for Destruction of their own Species, by the bloody Art of War. Some waste their whole Lives in studying how to arm Death with new Engines of Horror, and inventing an infinite Variety of Slaughter; but think it beneath Men of Learning (who only are capable of doing it) to employ their learned Labours in the Invention of new (or even improving the old) Instruments for increasing of Bread." This noble statement of Tull reminds one of the foresight of Vergil, or of the bolder prophecy of Isaiah—"They shall beat their swords into plough-shares, and their spears into pruning-hooks." Tull was so confident of his work that he declared that "any one may now, upon solid arguments, contradict Aristotle himself publicly anywhere except in the schools."

Tull's system of horse-hoe husbandry received small favor in his time, but he gained a few strong adherents. A century later a strong advocate arose in the person of Samuel Smith, a clergyman of Lois-Weedon in Northamptonshire; and the tillage of wheat in drills or rows is still often called the Lois-Weedon system. We have learned to till for tillage's sake, and not merely to kill weeds or to make the land more easy to plant; yet, among modern farmers, tillage is rarely practiced with sufficient frequency to produce the best results. The one great drawback to the system or method is the cost of labor, but all experiments agree in showing that there is an enormous stock of native plant-food in the soil, and that tillage will enable the plant to get much of it. Because of the element of manual labor in the proper tillage of the land, we are always falling away from it; and just now we are living in an era of commercial fertilizer. The general movement toward the use of fertilizer for the land is well illustrated in the transfer of meaning of the English word manure. This word first referred to the improvement of the land by means of manual labor, but it now applies only to the addition of substances.


Fig. 484. Jethro Tull.

Tull's theories were incorrect, but his practice was good. Add manure and drainage to his system, and we have an effective method of treatment of the soil. Tillage is surely of first importance; and every commonwealth might well raise a monument to the memory of Jethro Tull.

But there is another feature of this intra-cultural tillage to which attention may be called: it is exerting a powerful influence on the amelioration of the vegetable kingdom. Knight, Darwin and others have shown that abundance or excess of food supply is a cause of variation in plants; and as tillage greatly augments the usable food supply, it affords one of the means by which plants are made to assume new forms. The first, and probably most important, variation that arises when plants are brought under the hand of man is in the direction of luxuriance or increase in size. A moment's reflection will recall the fact that the chief difference between wild and cultivated plants lies in the relative sizes of the fruits or other valuable parts; and that any given variety of fruit or other crop usually holds its greatest size only under the most liberal cultivation, and that the greater the neglect of tillage the more completely does the variety depreciate toward the untamed type. The more expert the horticulturist, the more dependence does he place on particular strains and sub-varieties of his own origination. This is especially true in vegetable-gardening, where the "market-gardener's private stock" represents a certain high state of cultivation, and the seeds of this stock are likely to fail of good results in every place where the tillage and other treatment is less intense than under the conditions in which it was bred. There is a constant tendency, as tillage improves, for every individual farmer to develop his own types of plants; and so it happens that there may be a score of different types bearing one varietal name. The more diverse and intensive the agriculture, the more extended is the list of varieties that are demanded by it; and the varieties must be forever changing if adaptation to environment is complete.

With the invention of numberless machines for all kinds of purposes, there is danger that we overlook the importance of the simpler tillage tools. In the early days the plow was not obscured by such inventions. The Philadelphia Society for Promoting Agriculture, apparently the pioneer of the American agricultural organizations, adopted a plow as its emblem (Fig. 485), and gave a medal that had an image of a plow on one side (Fig. 486). One of the early technical agricultural books (Utica Plow Trial) was devoted wholly to plows, and the subject has not received so full and careful treatment since in this country. It is gratifying that the United States Department of Agriculture holds to the plow as its emblem (Fig. 487). The student who is particularly interested in the subject of plows and plowing should consult Behlen's "Der Pflug und das Pflügen bei den Römern und in Mitteleuropa in vorgeschichtlicher Zeit," 1904. The Editor has purposely been liberal with descriptions and pictures of plows and other tillage implements in this Cyclopedia.

Jethro Tull was born in 1674; he died in 1740. Before his day, seeds were sown broadcast, and little subsequent tillage was given. Tull advised more thorough preparation of the land, invented a drill for the sowing of seeds in rows and also horse tools for tilling the land when the plants were growing. For his inventions he was bitterly opposed and abused by his contemporaries. Most of the applications were for wheat, but the principles will apply to nearly every crop, aside from grass. Even at this day, we do not till our wheat, at least not in humid regions, but we use the drill. A great value of Tull's writing was the fact that it was founded on experiment. Tull may be called the father of scientific experiment in agriculture, at least in English-speaking countries. Everywhere the "old husbandry" was challenged by the "new husbandry." In North America Tull's system came under the scrutiny of Jared Eliot, our first agricultural author, as early as 1748. The ideas set going by the "new husbandry" echo through most of our agricultural writings even to the opening of the nineteenth century. Wherever it was advocated, the merits of Tull's husbandry were to be determined by experiment. Moreover, these experiments were to be worked out by means of implements of new principles and design. With Tull begins, also, the evolution of modern farm machinery.

Fig. 485. Emblem of the Philadelphia Society for Promoting Agriculture.

What novelties Tull's ideas were, is shown by Jared Eliot's mention of them in 1748: "In the former Essay, what I proposed for this Years Entertainment as curious and useful, was that profitable Husbandry performed by the Drill Plough; which is an Engine by which Wheat, Pease, Turneps, or what you will, are planted at proper distances, a fit depth, and covered all at once and with great speed: This sort of Husbandry is greatly Improved and much Practiced since it was first invented by the ingenious Mr. Tull. John Hubbard, Esq., of New Haven, who besides his other useful Qualifications, is of a mechanical Genious, upon whom I depended for help to make a Drill Plough; but he being in an ill State of Health I was deprived of that necessary assistance."

Fig. 486. Medal of the Philadelphia Society for Promoting Agriculture.

"*Explanation of the Medal:* A plough:—and oxen, at rest. One pawing:—impatient under idleness;—the other, looking for the arrival of the ploughman.—This emblem is preferred to the plough with horses;—to show, emphatically, the Society's desire to encourage the use of oxen, and the breeding of cattle." 1785. The title of the Society is wrongly given.

Although the knowledge of Tull's husbandry spread far and wide among reading and thinking men, the system met with much opposition from the farmers themselves. In the third and fourth editions of the "Horse-Hoeing Husbandry," 1751, 1762, the editors affirm that "it is but too true that few have made sufficient Experiments to be fully informed of its Worth." The inertia of the farmers was held to account for this state; "and, what is still more to be lamented, these People are so much attached to their old Customs, that they are not only averse to alter them themselves, but are moreover industrious to prevent others from succeeding, who attempt to introduce anything new." The editors mention the objections which had been urged to the tillage system. One objection was that it did not seem to be practicable on stiff and stony ground, and "that it hath not been practiced on either of these Lands in England we are willing to grant." But "the stronger the Soil is, the more Benefit will it receive from this Method of Culture, if the Land be thereby more pulverized," — a truth so familiar to us that we can scarcely conceive it ever to have been in dispute. Again "the Hoe-plough has been complained of, as cumbersome and unwieldy to the Horse and Ploughman."

Fig. 487. Emblem of the United States Department of Agriculture.

Tull's original writings are little known in America. Cobbett's edition (first published in 1822 in London) is the one that is oftenest met. Following is a list of some of the Tullian literature (not intended to be complete):

1731. The New Horse-Houghing Husbandry; or, an Essay on the principles of Tillage and Vegetation. Wherein is shewn, a method of introducing a sort of vineyard-culture into the cornfields, in order to increase their product, and diminish the common expence, by the use of instruments lately invented. London. Printed for the author, in the year M.DCC.XXXI.

The above is the entire title-page. Tull's name or initials do not appear in the work. The book is small 4to, 168 pages, with no illustrations. The following quotation is from the preface: "Writing and Ploughing are two different Talents; and he that writes well, must have spent in his Study that Time, which is necessary to be spent in the fields, by him who will be Master of the Art of Cultivating them. To write then effectually of Ploughing, one must not be qualified to write Learnedly. Scarce any Subject has had more of Ornaments of Learning bestowed on it, than Agriculture has, by ancient and modern Writers: But a late Great Man, who was the Cicero of the Age, having perused all their Books of Husbandry, ordered them, notwithstanding their Eloquence, to be carried upon a Hand-Barrow out of his Study, and thrown into the Fire; lest others should lose their Time in Reading them, as he had done. He declared, he could not, for his Life, guess what those Authors would be at; for they treated of an Art, wherein they had formed no manner of Principles." In distinction from these works, Tull declares that his book was "founded upon Principles, which if they be true (for I can only say I think them so) they must be, as all Truth is, Eternal; and yet are not extant in any Author, that I can find or hear of."

1733. The Horse-Hoing Husbandry: or, an Essay on the principles of tillage and Vegetation. Wherein is shewn a method of introducing a sort of vineyard-culture into the corn-fields, in order to increase their product, and diminish the common expence; by the use of instruments described in cuts. By J. T. Cum privilegio Regiæ Majestatis. London.

This book appeared in Dublin the same year, with "By Jethro Tull, Esq.," on the title. This 1733 issue is commonly taken as the starting-point of Tull's system. The illustrations were no doubt important factors in making this edition useful.

1751. Horse-Hoeing Husbandry: or, an Essay on the Principles of Vegetation and Tillage. Designed to introduce a New Method of Culture, whereby the Produce of Land will be increased, and the usual Expence lessened. Together with Accurate Descriptions and Cuts of the Instruments employed in it. By Jethro Tull, Esq., Of Shalborne in Berkshire. The Third Edition, very carefully Corrected. To which is prefixed, A New Preface by the Editors, addressed to all concerned in Agriculture. London.

The fourth edition, London, 1762, has the same title-page.

1753–7. Duhamel du Monceau. Traité de la culture des terres, suivant les principles de M. Tull, anglois. 5 vols. New ed. The first two volumes contain the exposition of Tull's principles. Tull's name does not appear on the last three volumes.

1784. Francis Forbes. The extensive practice of the New Husbandry. London. Second edition, 1786.

This book was published posthumously. It contains a note by the editor saying that Tull's final rules and opinions "lie almost smothered in the polemical appendices, etc. [of Tull's later editions] to which Mr. Tull was provoked by those literary vermin, that are as injurious to the agriculture of England, as the fly is to our turnips."

1822, 1829. The Horse-Hoeing Husbandry: or, A Treatise on the Principles of Tillage and Vegetation, wherein is taught a Method of introducing a sort of Vineyard Culture into the Corn-Fields, in order to increase their Product and diminish the Common Expense. By Jethro Tull, of Shalborne, in the County of Berks. To which is prefixed, An Introduction, Explanatory of Some Circumstances connected with the History and Division of the Work; and containing an Account of Certain Experiments of recent date, by William Cobbett. London.

The Lois-Weedon system, which is the modern rehabilitation of Tull's wheat tillage, came forward in 1849 through the publication of a booklet called "A Word in Season to the Farmer." This was written, anonymously, by Samuel Smith, Vicar of Lois-Weedon. Subsequent issues are as follows, all anonymous, but by the same author:

1854. A Word in Season; or How to Grow Wheat with Profit. Addressed to the stout British farmer. With a word or two more to those who have tried. Thirteenth edition. London.

1856. Lois-Weedon Husbandry. By the author of "A Word in Season to the Farmer." London. Small 8vo. Pp. 118.

1861. A Word in Season; or, how to grow wheat with profit. By the author of "Lois-Weedon Husbandry." Eighteenth edition. London.

1862. Lois-Weedon Husbandry as it is. Third edition. Including a "Word in Season about Growing Wheat," corrected and condensed. London. Small 8vo. Pp. 78.

While the Lois-Weedon discussion was in progress, another author came into the field:

1859. Alexander Burnett. Tillage a substitute for manure, illustrated by the principles of Modern Agricultural Science, and the precepts and practice of Jethro Tull. London.

The portrait of Tull on page 375 is drawn from a print accompanying Earl Cathcart's account of the life, times and teaching of Jethro Tull, in Journal of the Royal Agricultural Society of England, 3d series, vol. 2, 1891; and the print is a half-tone reproduction from "a contemporary painting in the possession of Mr. Martin J. Sutton."

TILLAGE: ITS PHILOSOPHY AND PRACTICE

By *F. H. King*

The art of tillage embraces all of those operations and practices which have for their object the fitting of the field and of the soil for the reception and the carrying to maturity of any crop. Ordinarily there is grouped under tillage, plowing, harrowing, rolling, cultivating and hoeing; but, in the fuller sense, there should be included all manipulations and treatments of whatever sort which shape and fit the field, or modify and adapt the soil so that thereby there results an efficient and wholesome feeding and abiding place for the crop.

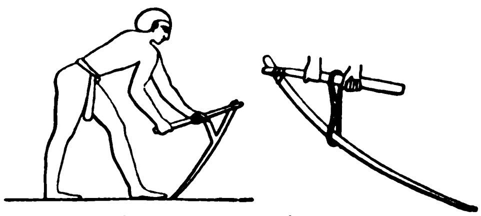


Fig. 488. The Egyptian sarcle.

Tillage is one of the oldest of the industrial arts, and must have had multiple centers of origin during the earliest cultural stages among all races of people wherever climatic conditions have permitted. Reference to its implements are found among the sculpturings on the ancient pyramids of Egypt, and the sarcle, represented in Fig. 488, doubtless is a type of one of the very earliest of the man-power tillage tools. In Fig. 489 is represented the same instrument, but made of steel and wood, as the writer saw it in the hands of three men plowing a level 5-acre field in Switzerland in 1895. More remarkable still, perhaps, will be regarded "the last of the breast plows," portrayed in Fig. 490, as built and used in 1904 in the midst of the world's highest culture and refinement, not 100 miles from the heart of London, England. But such instances are not to be looked on as cases of stolid conservatism or lack of mental capacity. Rather are they to be regarded as striking examples of that individual independence and power of adaptation which has always been characteristic of individual men standing for themselves, especially among agricultural peoples, leading them to make the utmost out of the resources which, for the time being, are immediately available to them. And so while it is an enormous interval of history that stretches between the old two-animal Egyptian wooden plow of more than 4,000 years ago, depicted in Fig. 491, and the present turning and pulverizing, nearly ideal, hardened steel plow of Figs. 227 and 243, and the engine-driven 16-gang set of plows frequently found on bonanza farms, and while the difference in efficiency between them is perhaps even greater, relatively, than the long reach of time that stands between, it is both helpful and encouraging to realize that the successive steps of advance which lead from one to the other, slowly as they have been taken, have yet followed one another quite as rapidly as the advance in structural materials and methods has rendered it possible; and especially is this the case when it is observed that the steps of advance, generally, have been suggested and very often initiated by the farmers themselves. And so in the case of "the old and the new in Spain," represented in Fig. 492, there must be conceded to the man behind the plow not only a high order of courage, to meet the duties of life under such strenuous conditions, but marked creative ability as well, to have hewn from the woodland so shapely a tool. That this plow is a product of the twentieth century only calls for higher praise for the man who has made so much out of his limited opportunities.

Objects of tillage.

Stated in the broadest and briefest way, the

Fig. 489. The chopping spade, still in use in Switzerland for plowing fields.

purpose of tillage is to develop and maintain beneath the surface of the field a commodious and thoroughly sanitary home and feeding ground for the roots of crops and for the soil organisms that help to transform the organic matter and the less soluble forms of the mineral plant-food materials of the soil into more soluble and suitable conditions adapted to the immediate needs of plants. But to make the habitable part of the soil of a field commodious and sanitary, and at the same time to maintain within it a sufficiently rapid development of readily water-soluble plant-food materials so conditioned as to be highly available to the crop, requires careful attention to many essential details. Some of the chief objects of tillage are:

(1) To secure a thorough surface uniformity of the field, so that an equally vigorous growth may take place over the entire area.

(2) To develop and maintain a large effective depth of soil, so that there shall be ample living room, an extensive feeding surface and large storage capacity for moisture and available plant-food materials.

(3) To increase the humus of the soil through a deep and extensive incorporation of organic matter, so that there may be a strong growth of soil micro-

Fig. 490. "The last of the breast plows."

organisms and the maintenance of a high content of water-soluble plant-food materials.

(4) To improve the tilth and maintain the best structural condition in the soil, so that the roots of the crop and the soil organisms may spread readily and widely to place themselves in the closest contact with the largest amount of food materials.

(5) To control the amount, to regulate the movement, and to determine the availability of soil moisture, so that there shall never be an excess or a deficiency of this indispensable carrier of food materials to and through the plant.

(6) To determine the amount, movement and availability of the water-soluble plant-food materials present in the soil, so that growth may be both rapid, normal and continuous to the end of the season.

(7) To convert the entire root zone of the soil into a commodious, sanitary living and feeding place, perfectly adapted to the needs of the roots of the crop and to the soil organisms,—adequately drained, perfectly ventilated and sufficiently warm.

(8) To reduce the waste of plant-food materials through the destruction of weeds and the preven-

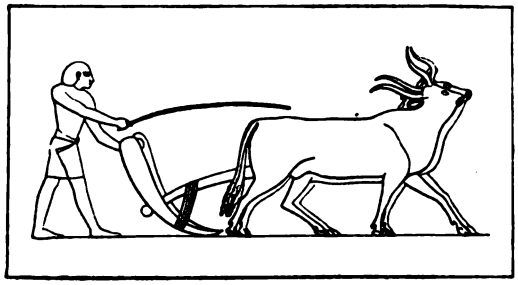


Fig. 491. Ancient Egyptian plow at work.

tion of their growth, through prevention of surface washing and drifting by winds.

Conditions determining the productive capacity of fields.

Before discussing the objects, aims and methods of tillage, it will be helpful to point out in a brief but comprehensive way some of the chief factors which determine the productive capacity of fields. In the first place, it must be pointed out that the conditions which determine the productive power of a given acre or of a given field are numerous and their inter-relations very complex. Some of these conditions are beyond essential modification by the agriculturist, and his course of procedure must be adjusted to them. Some of the factors, which cannot be directly controlled, are subject to abrupt and often marked fluctuations that require judgment, founded on experience, in order to be able to adjust other factors to them. Still other factors are so little understood, or are so obscure in their effects, that the line of action with reference to these must be guided by pure empiricism or left to mere chance.

The growing of any crop must be regarded as essentially a feeding enterprise or problem. As such it differs in no fundamental way from the maturing of an animal for the purpose of marketing its carcass or the products that may be produced by it. Just as with the animal, so the crop to be grown must be placed under those conditions of temperature, sunshine and humidity which, through evolution and long centuries of inheritance and adaptation, have become indispensable to its normal development. As in the feeding of stock it is necessary to supply continuously in abundance a well-balanced ration of food materials that are highly assimilable, so must these

Fig. 492. The old and the new in Spain.

conditions be met for each and every crop. Feeding conditions are not right unless the stable, yard or pasture are provided with an abundant supply of wholesome water; and an ample but not over-abundance of soil moisture continuously maintained throughout the root zone is a prime factor in the productive capacity of soils. It is not simply as an essential food material that water is so important in maintaining the animal functions. It is the medium for conveying all other food materials to the tissues and for removing waste materials from them. Within it and through it as an essential medium, occur all of those complex chemical and other reactions that are associated with growth, with repair, with waste and with the development of energy. It gives turgor to the cells, form and rigidity to parts, and maintains all absorbing tissues in functional condition. Through the cooling effects which result from its evaporation, it plays an important part in the control of temperature. In all of these ways is water essential to growing crops as well as to animals; and the uneasiness and suffering which animals experience from thirst are Nature's warning to them that the water in the system is getting low and that the bodily functions are being disturbed thereby. Entirely similar derangements of functions and processes occur in the plant when a deficiency of moisture obtains, and a checking of growth with reduced yields is the necessary result.

It is not unusual to regard a fertile field, in its power to produce, as quite analogous to a well-appointed feeding barn fully stored with an over-abundance of food materials of all essential kinds, except water and air. Such a conception, however, is far from expressing the true relation of a rich soil to the crop maturing on it. The barn is a lifeless storehouse to which animals are brought for a time to mature and be fattened. Not so a fertile soil on which a field of wheat is ripening. Much more nearly does the analogy hold when the comparison is made with animals grazing in a luxuriant pasture of mixed nutritious herbage, which grows day by day, now faster and then not so fast, as it is fed away, until the cold of winter checks and then entirely stops its growth. Within the body of the soil, if it has a high producing power, there are countless millions of living forms, invisible to the unaided eye, which spring into being, pass through life's phases, reproduce their kind and then die. As these flourish on the organic matter, the moisture and the mineral-food materials carried in solution and in the air of the soil, they produce, through their growth and through their death, through their interaction among themselves and on the soil, its moisture and its air, then and there, day by day as the season advances, food materials in soluble form, which are very essential to the life of higher plants and which determine in a high degree the immediate productive capacity of soils.

With the statements just made, it will be seen that in a very important and in a very fundamental sense the soil is a home or habitation in which dwell in close association not only multitudes of microscopic life but the roots of higher plants as well. For the accommodation and sanitary housing of such communities it is clear that there must be room, an adequate water-supply and ample ventilation and drainage. The physical or structural condition of the soil is, therefore, one of the most important factors which help to determine its productive capacity. It is the structural conditions chiefly, coupled with the temperature and with the substances carried in solution, that determine the absolute capacity of a soil for water, the amount of the stored water which may become available to the crop growing on the ground, together with its drainage and capillary movements. So, too, are the circulation of air in the soil, and the freedom and extent of penetration of roots and soil organisms dependent on the structure; and these in turn profoundly influence productive capacity.

Every field, like the individual horse or cow, possesses a specific capacity, a normal power of production to which it may be raised and at which it should be maintained. This specific capacity depends on the amount of organic matter that may be incorporated with the soil without entailing excessive waste; the absolute amount of plant-food materials possessed by the soil; the rate at which the chemical, physical and vital activities convert the mineral and organic ingredients of the soil into soluble forms suited to the needs of crops; and on the rate and economy with which the soil is able to deliver to the crop the soluble food materials so elaborated. It remains, therefore, for agricultural science and agricultural education to devise the means and the methods by which the future generations of farmers shall be led to know the fields of their farms as individuals, and to treat them as such according to their peculiarities, for only in this way may the highest productive capacity be economically attained.

Not only do fields possess a specific capacity of their own, but, as with cows and horses, there are certain purposes to which they are peculiarly adapted, while to others they can seldom be devoted with the highest pecuniary returns. The beef type of cow is never made to convert feed into butter with the same cost that the true butter types require; neither can the horse whose type of build adapts him for speed be economically used for heavy draft purposes. Local conditions, as market facilities, may make it advisable to grow crops to which the soil is not best adapted, but when this is necessary the earnings must be less than they would be could the adjustments be better. Another factor, therefore, which contributes to a high productive capacity of fields, is a selection of crops for them to which the soils are well adapted.

Every horseman, every dairyman and every machinist recognizes that no matter how inherently capable and true to type the horse, the cow, or the machine may be, the productive capacity of the individual, the quality of the product and the net returns depend in a very high degree on the healthfulness, vigor or condition in which the working unit is maintained, and on the intelligence and good judgment with which each is managed. In the highest degree are these things true of every field. An improper fitting of the surface soil; plowing when the ground is too wet or too dry; poor or inadequate cultivation for intertilled crops; a season too wet, too dry or too cold, may seriously reduce its productive capacity no matter how inherently fertile it may be. So, too, years of repetition with the same crop on the same field without change, and even a faulty succession or rotation of crops, may so alter its condition as seriously to cut down its productive capacity.

It is seldom true that notably rolling fields can be maintained at as high a mean productive capacity as more level fields of entirely similar types of soil. In estimating land values for purchase or for assessment, due consideration should be given to this fact. Many factors conspire to lower the mean productive capacity of notably rolling fields. Among these are the unequal distribution and efficiency of the rainfall or water applied in irrigation, which results from the surface flow of water from higher to lower levels, causing not only a deficiency of moisture on the more sloping areas but a serious reduction, often, of the immediately available plant-food material which is taken up by the water and borne to the lower, more level parts of the field, where it may be lost in the surface or underdrainage. Even when the side-hill wash is taken and retained by the more level parts of the field, the yield there is only occasionally notably increased thereby, while very often it falls away because of the downward displacement of the water-soluble plant-food materials present in the soil at the time the over-wash took place, carrying them to depths where they are not at once available.

The inherent productive power resident within the particular crop grown on the field; the vitality and vigor of the seed planted; the uniformity of stand over the entire area and the proper adjustment of this stand to the strength of the soil, are other conditions that have much influence in determining the productive power of fields. There are varieties of crops which are in themselves incapable of heavy yields, no matter how perfectly all other essential factors may be brought into adjustment and controlled. So, too, no matter how inherently fertile the soil of a field may be, or how well it may be managed, if poor seed is used or if an imperfect or an inappropriate stand is secured, a relatively small yield must be inevitable.

The effective product of a field, however, is not commercially measured by the stand on the ground when the crop reaches maturity; but rather by that part which is harvested successfully in suitable form for market or other use. It not infrequently happens that unfavorable weather at harvest time seriously cuts down the effective yield even with the shrewdest and most successful farmers. But it is lamentably true, and to a far greater extent than is really necessary, that the effective yields of fields are very largely reduced through lack of good judgment, lack of energy and alertness at the right time, and through a failure to appreciate sufficiently the fact that avoidable losses that occur at the "twelfth hour," when the matured crop represents the accumulated expenditures and earnings of the year, are the most serious of all in their effect on the balance sheet.

Surface uniformity of soil.

In developing any field until it has attained the maximum productive capacity at which it may be maintained, it is needful to secure for its entire area the nearest approach to uniformity and to maintain it continually in this condition. By surface uniformity of soil is to be understood an equality in producing power foot by foot over the entire field. Whether or not this condition has been attained in the management must be determined through observations from time to time as the crop advances toward maturity. These will be made by the successful farmer as he moves about from day to day, and areas where defective growth is evident will be noted mentally or in writing and studied, as the season advances, to learn if possible the difficulty and the remedy.

In securing surface uniformity on new lands, some one or more of the methods of clearing fields must be adopted, such as logging, grubbing, stump-pulling, the removal or burying of stone, and finally breaking, pulverizing and smoothing. On other fields superficial or underdrainage may have to be resorted to in order that the water content of the soil and the free space for air circulation may be uniform and suited to the needs of the crop. In countries where irrigation is to be practiced, very special attention must be given to securing uniformity of slope in order not only that the water may be economically distributed, but also that all parts of the field may be uniformly wetted. In other cases, when the character of the soil, of the rainfall and of the topography are such as tend to produce surface-washing, gulleying, or the removal of water-soluble plant-food materials from the sloping to the more level areas, methods of tillage must be adopted that will counteract these tendencies. Under still other conditions, especially in times when the fields are naked, wind-drifting may occur, thus tending to produce inequality of productive power by drifting away the finer soil particles, the organic matter and the soluble plant-food materials that accumulate at the surface under the influence of capillarity during drying times, causing them to collect in sheltered places, along fences, or bearing them entirely off the farm. Then there is the detail surface-finish or fitting that it is necessary to give to every field preparatory to seeding, securing for every part evenness of surface, uniformity of texture and equality of distribution of manure or of other fertilizers when they are applied to the field.

With the mechanical devices that are now available for forcibly drawing strongly-rooted stumps, second growth and even trees of considerable size from the ground, it is not now necessary to wait so long as in earlier times before the fields opened in forest regions may be entirely freed from surface obstructions. One of many types of stump-pullers is illustrated in Fig. 493. In cases when but few scattering stumps are to be removed, this may be accomplished with the aid of dynamite. This is on the market in the form of cylindrical, paper-covered cartridges for such service, and one of them suitably placed and discharged beneath a stump is usually sufficient to shatter it so that it may be readily removed.

But it will seldom be found economical, even with stump machines, to remove trees or freshly-

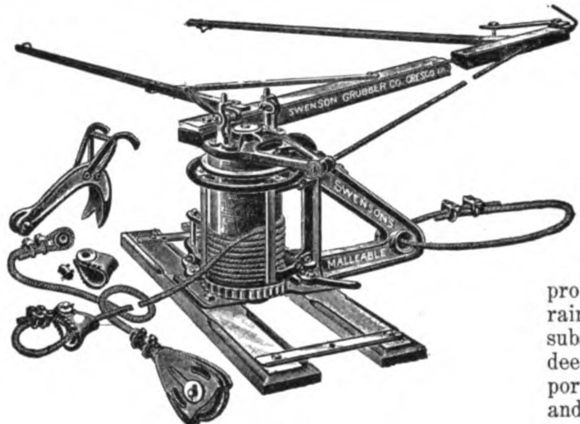


Fig. 493. Stump-puller and grubber.

cut stumps when they are larger than 6 to 8 inches through. In clearing such lands, a period of browsing, grazing and hay-making must usually intervene, in which second growth is kept down while the roots are given opportunity to decay sufficiently for the stumps to come away without bringing much earth with them. In getting such fields into grass after the logs and brush have been removed, it is often possible partially to fit the surface with the aid of a short spading harrow, cutting up the turf sufficiently to permit the sowing of clover and timothy with some grain, as wheat, oats or barley, for a nurse crop, covering the seed and smoothing the surface with an A-harrow, which is moved readily among stumps.

In striving to secure surface uniformity for a field, the presence of stone, especially if they are largely below the surface, may be endured somewhat longer than stumps; but as soon as practicable they should be removed or sunk below the depth of plowing. They are dangerous and destructive to machinery, wasteful of time and energy and provocative of bad temper; and they reduce the productive capacity of the field far too much to tolerate their presence long. The only questions are where to put them and how to get them there. A considerable quantity of such stone of suitable dimensions is a valuable asset, as they will be needed for building purposes, and they should be placed where they will be available. Others may be used to advantage to take the place of the bottom wire or bottom board in permanent fences. Many may be used to good purpose in building approaches to barn and stable doors, facing them with a thin layer of concrete. Foundations and floors of corn-cribs, granaries and tool-houses may be made of these, faced with concrete, making them very durable and vermin-proof.

The surface washing of fields is one of the strong factors tending to develop an unequal productive capacity in different parts. Its effects are most injurious when the field slopes are steep; when the rainfall is heavy and torrential in character; when the detail surface finish, like ridge- and furrow-planting and cultivation, gathers the water into streamlets; when the texture of the subsoil makes deep percolation slow; and above all, when the granular structure of the soil is so feeble that the compound grains readily break down, separating into their minutest particles under the shock and thrust of the raindrops as they fall, over-saturate the surface soil and flow down the slopes.

The most important and fundamental of the conditions tending to lessen and prevent the bad effects of surface washing is a deep and strong granulation of the soil, which provides a large reservoir capacity into which the rain may sink as rapidly as it falls. Opening the subsoil deeply by growing in rotation strong- and deep-rooted crops, like the clovers, is another important preventive measure. When it is physically and commercially practicable to do so, fields that wash badly should be kept as much as possible under such crops as bind the surface soil with a dense mat of strong roots, and such as send their roots deeply into the subsoil, tending to make it more open through the effect of the decay of the organic matter, to granulate the subsoil and to induce earthworms to penetrate further below the surface by providing organic matter on which to subsist. In cool climates and on soils not subject to frequent long droughts, some of the grasses and clovers are well adapted to securing these ends.

But during the time when intertilled crops, which do not completely cover the surface, are grown on fields that wash badly, it is often necessary to resort to other means to lessen surface washing. Planting the rows more or less nearly along contour lines is one of the most available measures, as under these conditions the ridges and furrows maintained during cultivation, and which are laid out so as to be horizontal, collect the water and retain it in the level furrows, giving it better opportunity to percolate and preventing it from gathering into rills. In regions where the tendencies to wash are strong, there are some fields in which planting along contour lines does not give sufficient protection, and in such instances more or less strongly developed and permanent contour ridges must be constructed to reinforce the restraining influence of level rows. [See page 402.]

After a field has been cleared and given its final surface features, with the conditions for maintaining them, it becomes one of the finished working-units or earning-assets of the farm; and in handling it as such, the detail surface fitting that adapts it to the reception of the next crop is one of the most important prerequisites to securing large yields. In giving to a field the detail surface fitting needful to secure the highest productive capacity, it is necessary (1) to turn beneath the surface to the best depth all vegetable refuse and organic matter which may contribute in any way to an improved condition of the soil, or which, if left on the surface, would interfere with the growth of the crop; (2) to leave the field so smooth and even and the soil in such a condition of tilth that, in sowing or planting, either with machinery or by hand, there will be secured uniformly over the field the same depth of planting, and the best conditions for vigorous, quick and complete germination; (3) to secure that depth of seed-bed, amount of moisture, degree of heat and openness of texture that will permit the particular crop to develop, from the nourishment stored in the seed during the time it lasts, the strongest possible root system uniformly, deeply and widely spread in the best working connection in the soil; (4) to develop and maintain in the field, as deeply and generally as may be, those congenial qualities of loamy mellowness so indispensable in any soil as a home, laboratory and feeding ground for those life activities that help to elaborate the more readily soluble plant-food materials, which must be continuously renewed, in all soils of high productive capacity, as they are used by the roots of crops; (5) to incorporate with and disseminate through the soil as thoroughly, intimately and uniformly as may be, any stable manure, fertilizers or correctives that it may be advantageous to apply to the field from time to time.

The securing of the several important objects enumerated as the aims of detail surface fitting are comprised under the good farmer's "thorough preparation of the seed-bed." The chief tools employed in accomplishing these results are the plow, pulverizer, harrow and roller, each of which is made in several types. [See page 387.]

Deep fitting of fields.

The superior productive capacity of fields possessing a deep soil is generally recognized. So, too, is their power of endurance. But the significance of depth, as an important factor of productive capacity, is not taken into account in tillage operations and in the management of soils as much as it deserves to be. The marked increase in the productive power invariably exhibited by "back-furrows," and the much more pronounced decrease in the "dead-furrows," in all humid climates are unequivocal demonstrations year by year which make evident what the productive capacity of the fields would be were the fields all "back-furrows" or all "dead-furrows"—were the true soil, as contrasted with the subsoil, made deeper or more shallow, as is the case with the "back-furrow" and with the "dead-furrow." The generally high productive power of the soils of arid regions, of the bottom lands of streams, of the flood-formed and wind-formed loess soils of glacial times, and of thoroughly underdrained, mellow, loamy soils of every type, is due in no small degree to an effective depth which is greater than usual.

The essential conditions of effective depth of soil are (1) a thorough, deep and strong granulation; (2) an abundant and deep incorporation of organic matter; (3) an adequate underdrainage. When these conditions co-exist, the soil moisture will be retained in sufficient abundance and in such a way as to permit an adequate interchange of air to take place; at the same time, heavy rains will penetrate the soil deeply and rapidly, the excess will pass quickly into the underdrainage, while that which is retained will be least turbid and most available to the crop and to the microscopic life in the soil. When wholesome soil water and soil air, and suitable organic matter occur in abundance, well and deeply distributed through the soil, there both the microscopic soil life and the roots of crops will follow, and we have an effectively deep soil in the sense here considered. Its productive capacity will be large because its available and effective surface per acre of field is large, on which microscopic life may multiply and in association with water and air transform organic and mineral matter into plant-food materials, spread out where an extensive root surface may be brought into advantageous relations with them. The object of deep fitting of fields is to establish and maintain these very essential conditions of a highly productive soil.

The instrumentalities that may be used in securing a deep fitting of fields are: (1) underdrainage, when this is not naturally sufficient; (2) growing in rotation crops which have a strong, deep root system, thus carrying the organic matter downward and leading to a deeper penetration of earthworms; (3) subsoiling, when the ground is not too wet, using tools which break the earth rather than simply set it aside by compression; (4) trenching and the very deep plowing such as is done by steam power on some sugar plantations; (5) deep fall plowing and winter weathering; (6) deep plowing and naked summer-fallowing; (7) progressively increasing the depth of plowing; (8) plowing under deeply stable and green manures; (9) plowing deeply, using a plow with steep moldboard when the upper subsoil is in the right condition of moisture to pulverize well; (10) liming and the addition of other flocculating agents; (11) leaching by underdrainage for the removal of alkalies.

Incorporating organic matter in the soil.

One of the chief objects of tillage is the deep and thorough incorporation of organic matter in the soil where it may be converted into humus, and where it may undergo transformations in the active root zones. When it is understood that the main immediate source of nitrogen for the higher plants is the organic matter which the soil carries, and that which is fixed from the soil air by nitrogen-fixing soil organisms, to whose activity organic matter in some form is indispensable, the great importance of its thorough incorporation with the soil becomes clear. Then, too, the amount of nitrogen required by crops is larger than that of any other plant-food material taken from the soil, except water. It is the most expensive of the plant-foods if it must be purchased on the market; and when converted into nitric acid, the form in which it is available to crops, it is in the greatest danger of being lost by surface washing, by leaching and by denitrification. Moreover, it is and must be sold off the farm in larger quantities than either potash, phosphoric acid or lime; next to soil moisture, the variations in its available amounts are oftenest responsible for high and low yields.

Not only is the nitrogen, in the form in which is it chiefly available to crops, derived largely from the organic matter incorporated with the soil, but when the amount of organic matter in the soil is large the soluble forms of most of the other essential plant-food materials are likely also to be large.

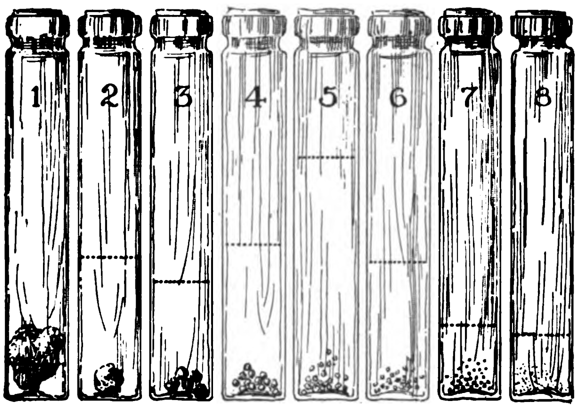


Fig. 494. To show the granular character of a soil in good tilth after cultivation. The granules were sorted by a series of sieves. The relative amount of each size of granules is represented by the dotted line in each vial. It will be seen that the largest size, No. 1, constitutes the smallest part of this soil, and No. 5 the largest.

That such a relation should exist is to be expected for the reason that within the plant tissues, whose decay yields the organic matter, there has been collected from the soil moisture taken up by the crop and transpired through the foliage much of the soluble salts carried by the water in the soil at the time. And it is not unreasonable to expect that we shall yet learn that other and more valuable combinations with these plant-food ingredients are formed during their association under the vital processes of the plant, and that, when the tissues are again breaking down in the soil when closely associated with active roots, they are again absorbed and may contribute in an important way directly to plant growth.

In the case of stable manure, too, which must be regarded as finely comminuted organic matter brought into admirable condition for incorporation with the soil, there is a very high percentage of readily soluble substances concentrated first by the crop and then by the animal fed on it. Some of these, because they have recently been functional in plant growth or in animal nutrition, may remain for some time in the soil in forms directly utilizable by the crop on the ground and by the microscopic soil organisms.

But organic matter is of great importance, through its physical effects, in giving to the soil that granular structure which constitutes good tilth, leading to better reception of rain, better drainage, better ventilation, stronger capillary movement of water, deeper root penetration, less loss of plant-food by leaching, and a much higher efficiency of soil moisture. Thus, aside from mere plant-food, it is of the greatest importance to maintain incorporated thoroughly and deeply in the soil an abundant supply of organic matter slowly undergoing decay.

To maintain the high content of organic matter, dependence must be placed on the root systems of the crops grown on the field; on turning under judiciously the roughage and waste of the field in the form of stubble, weeds and crops not harvested; on green-manures and cover-crops, especially of the leguminous type; on soil organisms which have the power of fixing free nitrogen; and, best of all, on the manure of live-stock, because it is made up of the richest parts of all the others, reenforced, perhaps, with grain bought from outside, and all combined in superlative condition for thorough incorporation with the soil, and highly charged with the best of available plant-food materials.

The great problem of tillage in this regard is how to incorporate deeply the largest amount of organic matter rich in nitrogen. Much more attention needs to be given to turning under more deeply and more completely all roughage and waste, stable and green-manures, using the jointer on the plow, and a chain if necessary, to bring all such material completely under cover where it will have the maximum effect physically, chemically and biologically. The still deeper incorporation, which is needed, must be secured largely by growing grasses and legumes in rotation with other crops.

Maintaining the best soil structure, or good tilth.

Next in importance to an abundance of moisture well charged with the essential plant-food materials, is the best structure of the soil itself, by which is meant a good bunching or gathering of the ultimate soil particles into granules such as are shown in Fig. 494, which represents the granules of a clay loam in fair tilth which were sorted by screens from the loose earth as left after cultivating three inches deep. The relative amounts of the several sizes are shown by the heights of the dotted lines in the respective vials. There was present least of the No. 1 and most of No. 5. Even of the finest grade, No. 8, very many of the kernels are large enough to be readily distinguished with the unaided eye, although they are made up of particles of microscopic size. When a soil has its structure or tilth destroyed, the granules are more or less completely broken down, and in a thoroughly puddled condition the destruction of the kernels is carried to the extreme limit, and so long as a fine-grained soil is in this state it will remain entirely unproductive. This must be so (1) because with the close packing of such minute grains the movement of both water and air is too slow to meet agricultural requirements; (2) because the spaces between the grains are too minute for even root-hairs to place themselves between them; (3) and because it is impossible for soil organisms, essential to fertility, to develop and spread through a medium so poorly aërated.

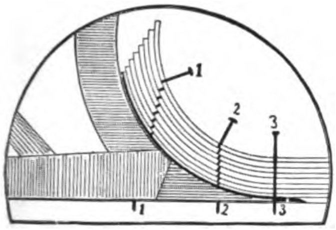


Fig. 495. Showing the principle of the pulverizing action of the plow.

For developing and improving the structure of the soil we now have two types of tools which are admirably suited to the purpose,—the moldboard plow for depths of 5 to 12 inches, and the revolving disc harrow for more shallow work. The principle underlying the pulverizing action of the moldboard plow is illustrated in Fig. 495. A plow is there represented as running under a pile of eight flexible layers or sheets. As they are forced up by the plow in its advance, each sheet is compelled to slide over the other, and even if the several layers were pinned together as represented at 1, 2 and 3, they would tend to shear off the pins as indicated in the cut. This action is very clearly shown by abruptly bending a lot of leaves in a book. Each leaf is then seen to have slipped on its neighbor, and the further the more abruptly the bending is done. The action of the moldboard plow on the furrow-slice is of the same character, tending to force the soil particles to slide or roll over one another, and through a greater distance the steeper the moldboard of the plow. The revolving disc harrow or plow, with its concave discs moving obliquely through the soil, tends to shear the soil layer much more than the ordinary plow, but its best service is rendered when used as a shallow tool and when the soil is not too wet.

In plowing to correct texture and to improve tilth, it must be remembered that very much depends on the shape of the moldboard, the wetness of the soil, and the depth of the furrow-slice. If a soil is the least amount too dry to puddle, a steep moldboard plow, such as shown in Fig. 243, will shear it into thinner layers and pulverize the soil most; if the soil is still drier, the layers will be thicker and the granules coarser. When the soil is much too dry no shearing will take place, and the furrow-slice will break into coarse lumps. If the soil is much too wet the pulverizing will be so great that the soil will be puddled. With a given plow the deeper the furrow-slice the greater will be the pulverizing effect and the greater the danger of puddling the soil if the soil is too wet. So if the plowing is done with a low, flat moldboard, like that of Fig. 496, the pulverizing effect on the soil will be much less than if a plow like the one in Fig. 243 is used, and the danger of puddling will be much less if the soil is very wet.

It is clear from the mechanical action of the plow that its form should be adapted to the type of soil. If the soil has a tendency to be too open and porous, and is naturally coarse-grained, like the sandy soils, it should be plowed with a steep moldboard when a little over-wet, and as deep as conditions will permit, so as to break down the granulation and secure a finer, closer texture. If the soil is generally too close in texture, is heavy and soggy, it needs to be plowed with a less steep moldboard and when the soil is a little drier, so as to shear into thicker layers and form granules of larger size. If the plowing must be done when the soil is a little too wet, a less steep moldboard should be used and the depth made as shallow as the conditions will permit. If the soil has become too dry and is not pulverizing enough, a steeper plow run at a greater depth will do the work better.

There are other ways of improving the structure of the soil, and there is, perhaps, none so effective and so enduring as that of thoroughly incorporating organic matter in one way or another. The organic matter falling into the spaces of the soil establishes parting planes which prevent the grains from reuniting when expansion follows with the wet season. The very great advantage of stable manure, in this direction, arises chiefly from its extremely comminuted condition which permits a thorough dissemination through the soil; partly also from the flocculating tendencies of the salts carried in it. Lime, especially, acts in this way on clay soils, and some of the mineral fertilizers do also, while others have an opposite effect. Some crops, as blue-grass and timothy, which are perennial and form a dense mat of roots that closely cross-divide the soil, exert a very pronounced granulating effect that is very helpful to

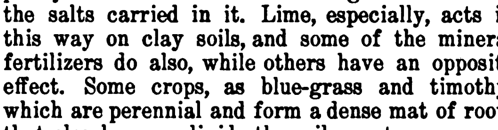


Fig. 496. Type of sod plow, which pulverizes but little.

heavy soils, largely in this physical way but also, perhaps, in providing conditions which enable some forms of soil organisms to add to the store of nitrogen in the soil. This is suggested by some of the results of the Rothamsted Station recently reported by Hall.

The action of freezing during the winter and of surface-drying in the summer are other conditions that act especially to overcome the bad effects of puddling, and they are agencies that may be employed, acting on the subsoil, in the methods of progressive deepening of the soil to which reference has been made. In these cases, the water held so firmly by the extremely fine clay particles is driven out and then, when wetting occurs again, the fine clay and also, perhaps, some of what had been colloid matter, no longer returns to that state but is gathered about other granules; in this way, the soil becomes more open and friable.

Soil moisture, available plant-food, soil temperature.

Many of the operations of tillage influence in important ways, and are often specifically directed

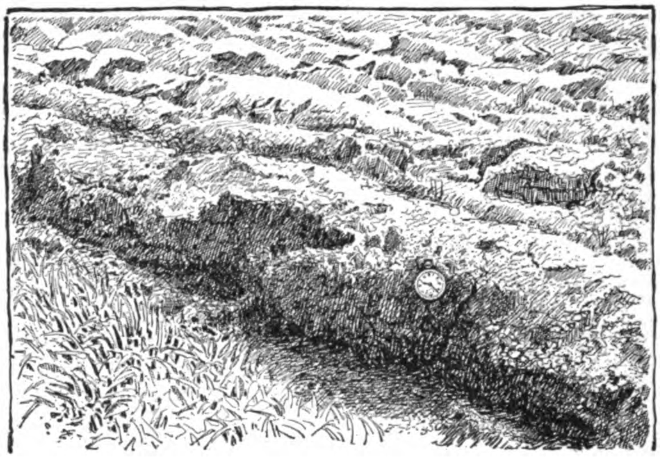


Fig. 497. Method of plowing. The furrow-slices turned on edge and left comparatively unbroken. Sod land.

toward effecting a control of or improvements in the conditions of soil moisture, available plant-food and soil temperatures. Surface tillage, as applied early in the season, particularly in the fitting of the seed-bed, should be made to influence the conservation of soil moisture, the development of available plant-food, and the temperature of the seed-bed.

In the very early fitting of the surface soil in the spring for the small grains, and for seeding to grass and clover, the shallow tillage that is given to fields plowed the previous fall and to land that had been in corn or potatoes the year before, that are to be seeded without plowing, should exert an important influence on the productive capacity of the field for that season. This influence results from the very large reduction in the loss of soil moisture by surface evaporation, which is effected by loosening the soil to a depth of three to four inches. The amount of evaporation from naked soil when wet and firm, as it is before tillage in the spring, is very large, and in clear, warm, windy weather may easily exceed two inches of rainfall per week. The writer has measured rates exceeding three inches, and mean rates for the growing season ranging from 1.1 inches to 1.5 inches on naked, firm soil maintained continually saturated by capillarity. This influence results also from the increase in the rate at which available nitrogen is developed in the loosened tilled soil and in the layer just below it, as the effect of better aëration and a higher temperature following the stirring. For this early fitting of the seed-bed, which has not been spring-plowed, it is doubtful whether there is a more effective tool than the disc harrow. It may readily be made to pulverize the soil to a depth of four inches, and, by lapping half-way, the work is very effectually done.

In the case of intertilled crops which are planted considerably later than the small grains, there is opportunity to develop the advantages of tillage to a greater extent. Very much may be gained by beginning the fitting of the field two or three weeks ahead of planting time in order to take advantage of naked fallow in increasing available plant-food and in giving opportunity once or twice for weed seeds to germinate; the weeds should be killed before the crop is planted. It is especially important, when green crops are turned under and when stable manure is applied, that early fitting should precede the planting by a considerable interval of time.

The tillage given to intertilled crops to conserve moisture through the development of earth mulches and the killing of weeds is very helpful along another important line, namely, in restraining the rise of nitrates and other readily soluble salts to the very surface, where they are above the reach of roots and in danger of being lost by surface washing in times of heavy rains. An earth mulch two to three inches deep has its effect in restraining the soluble salts to a level just below its surface; and apparently, through the slower rate of capillary rise, the nitrates diffuse downward again so as to be found more abundant six to twelve or more inches below the

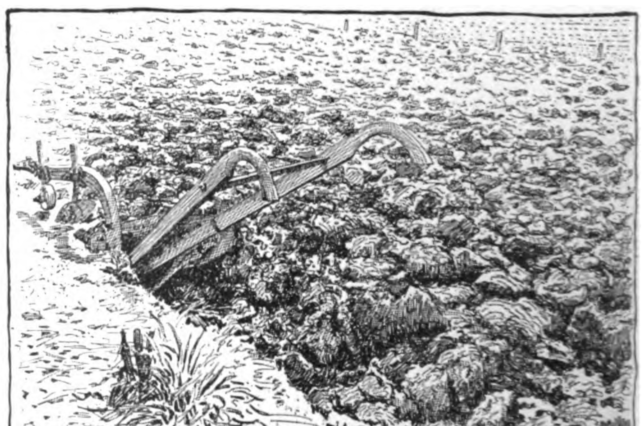


Fig. 498. Poor plowing in the same field as Fig. 497, but not in sod, and the land too dry.

surface, where the roots are also more abundant than they are in soil where no mulch has been maintained.

Literature.

The following publications should be consulted in this connection: Agriculture, by F. H. Storer, Vol. 1, Chapters V and VI; Agriculture, by William P. Brooks, Vol. I; Fertility of the Land, by I. P. Roberts; The Soil, by F. H. King; Irrigation and Drainage, by F. H. King, Chapter III; Physics of Agriculture, by F. H. King, Chapters VIII, IX and XI.

TILLAGE MACHINERY

By *J. B. Davidson*

When man first turned his attention to agriculture and had fields in which grain was planted, he began to devise tools to aid him with his work. It was found that plants grow larger and produce more when the ground is stirred. The tools first used were simple and inefficient, but they have been developed until now they seem almost perfect. Agricultural tools and implements used in preparing the soil for the seeding, planting or growth of crops may be classed as tillage machinery.

The objects sought by the use of tillage machinery are many and have been enumerated about as follows: first, to produce various textures of the soil that will render the most plant-food available; second, to cover under the surface green crops and other vegetable matter where it will decay quickly and add to the supply of humus in the soil and not hinder further cultivation; third, to destroy and prevent the growth of weeds and other vegetation not desired; fourth, to regulate and retain the moisture in the soil; fifth, to change conditions, as to modify the temperature of the soil; sixth, to modify the soil as regards root-penetration.

Too much stress cannot be laid on the importance of tillage machinery, for much of the increase in

Fig. 500. "A Spanish Plough, with one of which, and one Horse they will in Spain plough two or three Acres of their light Lands in a day." Mortimer, "The Whole Art of Husbandry," London, 1708.

production is due almost entirely to its introduction. By its proper use a given area is made to produce more and a larger area can be tilled. By the intelligent use of modern machinery the objects as set forth may be accomplished almost perfectly. The tool used in the preliminary operation of tillage is a plow, and as it is one of the first devices invented by man it will be considered first.

The plow.

The first plow was only a modification of the hoe of that age, a crooked stick so shaped that it penetrated and loosened the soil as it was drawn along. Man, at first, furnished the power, but later he enlarged this crude plow and drew it with the beast that he had been able to train for draft and burden. The ancient Egyptians had such a plow, and pictures of farmers plowing are to be found among the oldest records. They developed the plow until it had a beam, a shank and a handle. (Fig. 491.)

Fig. 499. "Rodgers Improved Scotch Plough," on which a report was made on March 24, 1818, by the Agricultural Committee of the Society for the Promotion of Useful Arts in the State of New York.

The next step in the development was to shoe the point and wearing parts with iron, and this was done very early, for it was written, 1,100 years B. C., that the Israelites, who were not skilled in the working of iron, "went down to the Philistines to sharpen, every man, his share and his coulter."

The Romans were among the first to develop the plow, and the Roman model remained for a long time as the standard plow. Vergil describes the Roman plow in the Georgics as having a point made of two pieces of wood meeting at an acute angle and being plated with iron.

During the middle ages the plow was developed very little, and those used resembled very much the Roman. The Dutch, owing to the conditions which they had to meet, were among the first to make changes of importance. The crude Roman type of plows did not give satisfaction on their soils. They found it necessary to give the moldboard a more perfect form and protect it with iron. Some of the early Dutch plows were imported into Yorkshire, England, as early as 1730. The Dutch plow was improved by Small, of Berwickshire, Scotland, until the major part of it was made of iron.

Small established a factory at Black Alder Mount, Scotland, and developed a large trade. The moldboard of this plow was finally made of cast iron, and the beam, handles and share of wrought iron. The English patent records show that a patent was granted to Robert Ransome, of Ipswich, England, for an improvement in the construction of the cast-iron share. This was followed in 1803 by one to the same man for case-hardening and chilling the share. In 1840 a plow factory was established by Mr. Howard, and the firm is still in existence. At about the same time a factory was established to manufacture Ransome's plow;

and this factory also remains to this day one of the largest in England. It is reported that the Howard and Ransome plows won prizes at the London and Paris Expositions of 1851 and 1855.

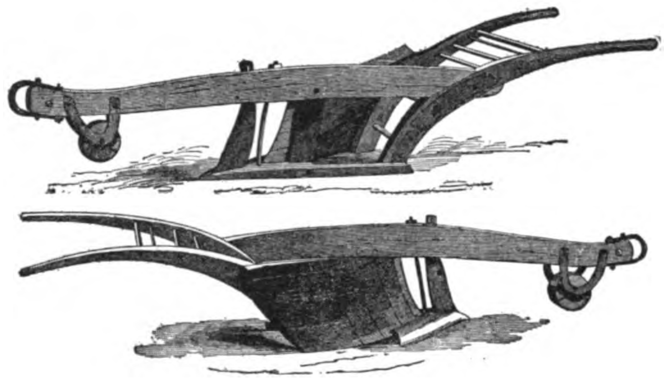


Fig. 501. Daniel Webster's plow.

Some of the early forms of plows are shown on pages 206–210.

The plow used by the colonists before the Revolutionary war did not differ much from those used in England at the time. Conditions were not such as to encourage the invention and manufacture of new tools. During the later colonial times the Cary plow was used, and it seems to be representative of the type then employed. It was described as having "wrought iron share, wooden landside and standard, and wooden moldboard plated over with sheet iron or tin, and short upright handles." In the Yearbook, Department of Agriculture, 1899, it is stated that the Old Colony plow, which was used in the eastern states in 1820, "had a ten-foot beam and a four-foot landside" and that it made the "furrows stand up like the ribs of a lean horse in the month of March."

Thomas Jefferson was among the first to give thought to the improvement of the plow. When abroad in France, he wrote · "Oxen plow here with collars and harness. The awkward figure of the moldboard leads one to consider what should be its form." Later he specified the shape of the plow by stating: "The offices of the moldboard are to receive the sod after the share has cut it, to raise it gradually and to receive it. The fore end of it should be as wide as the furrow, and of a length suited to the construction of the plow." Jefferson made elaborate mathematical studies of the proper shape for the working parts.

Daniel Webster also designed and helped to build a plow in the year 1836 to be used on his farm at Marshfield, Massachusetts. The plow was very large and cumbersome. It was designed to plow 12 inches deep or more, and required several men and yoke of oxen to run it. It was described as being "12 feet long from the bridle to the tip of the handles; the landside was 4 feet long; the bar and share were forged together; the moldboard was of wood with strip of iron; breadth at heel of moldboard to landside was 18 inches; the spread of the moldboard was 27 inches; the lower edge of the beam was 2 feet 4 inches above the sole; the width of the share was 15 inches." Webster, in speaking of his work with the plow, is reported to have said: "When I have hold of the handles of my big plow in such a field as this, with four yoke of oxen to pull it through, and hear the roots crack and see the stumps all go under the furrow out of sight, and observe the clean, mellow surface of the plowed land, I feel more enthusiasm over my achievement than comes from my encounters in public life in Washington." A picture of this plow is given in Fig. 501.

The first letter patent on a plow was granted to Charles Newbold, of Burlington, N. J., in 1797. (Fig. 502.) His claim read as follows: "The subscriber, Charles Newbold, of Burlington county and state of New Jersey, has an improvement in the art of plow-making, viz., the plow to be, excepting the handles and beam, of solid cast iron, consisting of a bar, sheath and mold-plate. The sheath serves the double purpose of coulter and sheath, and the mold-board serves for share and mold-board, i. e., to cut and trim the furrow." It is an amusing fact that the history of the times records that the farmers rejected Newbold's plow on the theory that so much iron being drawn through the soil poisoned it, retarding the growth of plants but stimulating the growth of weeds.

For some time there was little development from these simple wooden plows with the wearing parts protected with strips of iron. About 1830, what was known as the Diamond plow was brought into general use. The name was derived from the shape of the slab of iron that formed the moldboard.

The next step in plow development was recorded by a patent granted to Jethro Wood. (Fig. 242.) Wood's plow was made almost entirely of iron and the parts were made interchangeable. The form of the moldboard was also more perfect, the pressure being more evenly distributed over it, thus increasing its life. Wood's plow served as a model for the many designs to follow, but the inventor failed to be rewarded for his work; it is said he finally died in want. William H. Seward, Secretary of State under Lincoln, said: "No citizen of the United States has ever conferred greater benefits on his country than Jethro Wood; none of her benefactors have been so inadequately rewarded."

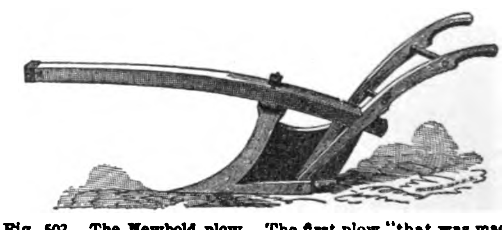


Fig. 502. The Newbold plow. The first plow "that was made of cast iron in this country," according to the work on the Utica Plow Trials.

On November 14, 1868, James Oliver secured a patent for hardening cast iron so as to make its wearing and scouring qualities better. Cast-iron plows of the time were filled more or less with

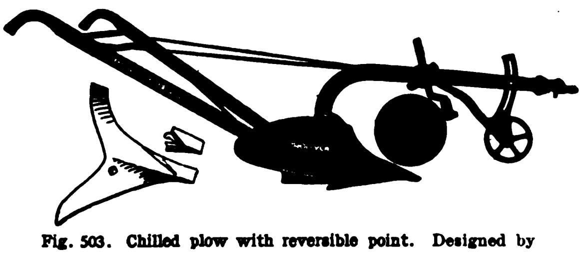


Fig. 503. Chilled plow with reversible point. Designed by Mr. Oliver.

small cavities called blowholes, which were very detrimental. By devising schemes to take care of the gases and steam that were formed in the mold when the metal was poured, these troubles were obviated to some extent. Mr. Oliver secured many patents on plows, among the most important of which was one on the "slip nose" share, as illustrated above. In this plow the nose may be reversed or replaced entirely when worn rounding. (Fig. 503.)

As farming moved farther west the early settlers found a new problem in the tough sods of the prairie states. A special plow with a very long sloping moldboard was found to be necessary in order to reduce friction and to turn the sod over smoothly. The firmness of the sods allowed the use of curved rods as a substitute for the moldboard. Later, when sod became reduced, it was found that the wooden and cast-iron plows used in the eastern section of the country would not scour well. This difficulty led to the use of steel

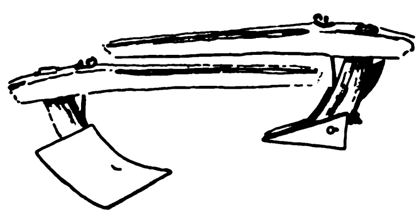


Fig. 504. Early steel plows made by John Deere, 1837.

in the making of plows. Steel, having the property of taking a very excellent polish, permitted the sticky soils to pass over the moldboard, whereas the other materials failed.

John Lane was among the first to make use of steel in plow-making. It is stated that about 1833 he made a plow of which the moldboard and share were formed of strips of steel cut from an old saw. Three strips of steel of different lengths were used for the moldboard, and one for the share. All of these were fastened to a "shin" or frame made of a three-cornered piece of iron.

John Deere, in 1837, at Grand Detour, Ill., made a steel plow of saw steel in a similar way. In 1847 Deere moved to Moline, Ill., and founded a factory which still bears his name. William Parlin was also a pioneer in the plow industry, and he established a factory at Canton, Ill., which also is one of the largest in the country. Fig. 504 is one of the first plows made by Deere. Much credit is due these men. John Lane, September 16, 1869, conceived of and patented soft-centered steel. This consisted of a layer of high carbon steel on each side of a soft center, and proved to be very much easier to temper without warping than a homogeneous steel or a steel with a soft backing, as brought out by a Mr. Morrison about the same time.

The sulky or wheel plow has been developed comparatively recently. The first successful sulky plow, i. e., one on which the operator rode, was invented by F. S. Davenport, February 9, 1864. Robert Newton, of Jerseyville, Ill., added to the

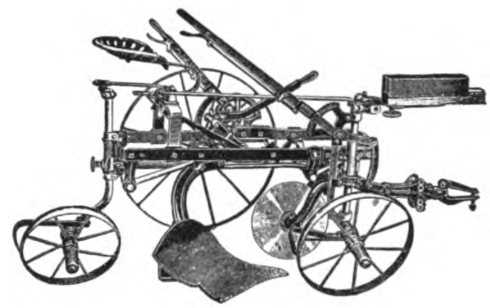


Fig. 505. A modern sulky plow of approved type.

Davenport sulky a rolling coulter and a three-horse evener. Gilpin Moore, with a patent of January 19, 1875, and W. L. Cassaday, with patent of May 2, 1876, were pioneers in the sulky plow development. Cassaday was the first to use a wheel for a landside. Many inventions and improvements have been added to the sulky plow, and it would require much space to mention them. The present day sulky or riding plow is represented in Figs. 244 and 505.

The modern plow as now made has the following parts, which are numbered as in Fig. 506.

(1) Share or cutting edge. The part of the share that penetrates the ground is called the point and the outside corner, the heel. A bar share is one welded to the landside, while a slip share is independent. (Fig. 507.)

(2) Moldboard: the part that turns the furrow. The lower corner of the moldboard is called the "shin."

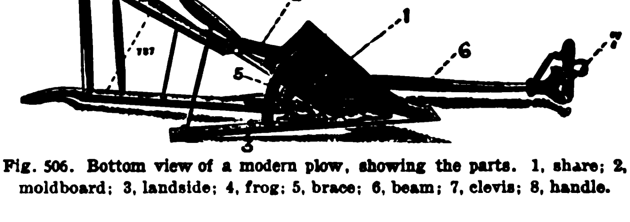


Fig. 506. Bottom view of a modern plow, showing the parts. 1, share; 2, moldboard; 3, landside; 4, frog; 5, brace; 6, beam; 7, clevis; 8, handle.

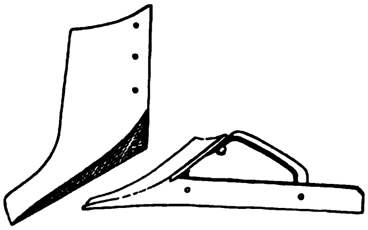


Fig. 507. Slip share on left, bar share on right. The bar share is welded to the landside, while the slip share is independent.

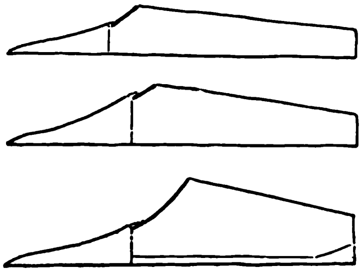


Fig. 508. Low, medium and high landsides.

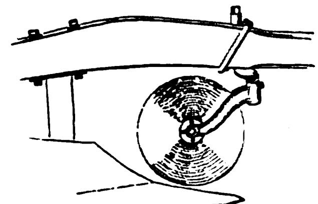


Fig. 509. Disc or rolling coulter.

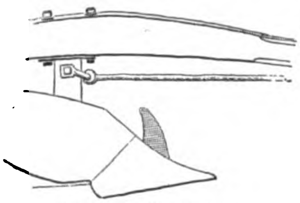


Fig. 510. Fin coulter.

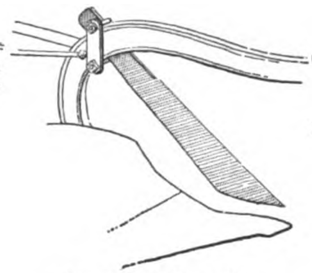


Fig. 511. Knife coulter.

Fig. 512. Characteristic styles of plow bottoms. The types vary from the long, sloping share and moldboard of the breaker plow (on the right) to the short, abrupt curvature of the old ground or stubble plow (on the left). The intermediate forms are for "general purpose" plows.

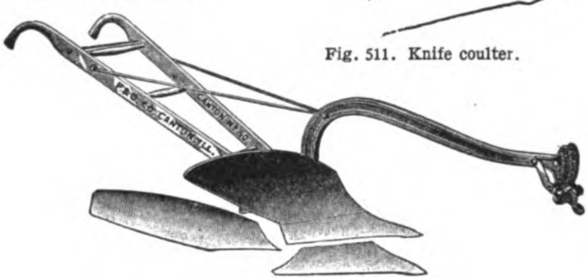


Fig. 513. Plow with interchangeable moldboard and share, and thus adapted to a variety of soils.

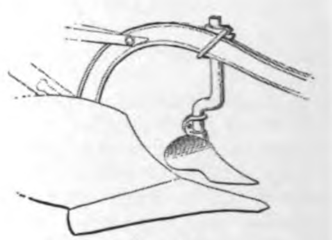


Fig. 514.
A common form of jointer.

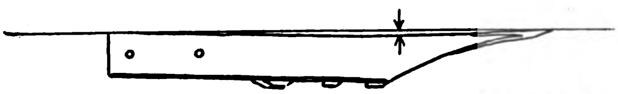


Fig. 515. Showing the suction of a plow. Suction is the amount the point is turned down to secure penetration.

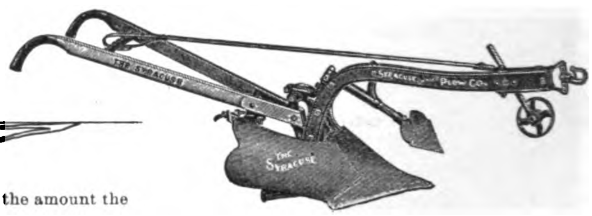


Fig. 518. A good type of hillside plow.

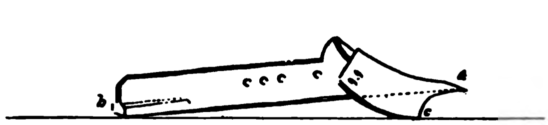


Fig. 516. Bearing at wing in a walking plow. The bearing is given to carry the downward pressure of the furrow-slice.

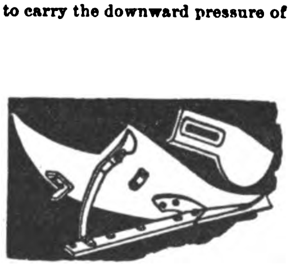


Fig. 517. Heel plate, used to vary the width of surface at the heel.

Fig. 519. Reversible or hillside plow, for use where the land is too sloping to throw the furrow-slice up hill.

(3) Landside: the part that takes the side pressure produced in turning the furrow. Landsides may be classed as low, medium and high landsides. Fig. 508.

(4) Frog: the frog is the foundation of the plow to which the share, moldboard and landside are attached.

(5) Brace.

(6) Beam: in a wooden beam plow a beam standard connects the beam to the plow.

(7) Clevis or hitch to adjust the plow.

(8) Handles: handle braces connect the handles to the beam.

(9) Coulter: coulters may be classified as rolling coulters, fin coulters and knife coulters. (Figs. 509, 510, 511.)

The moldboard, landside and share are usually made of soft center steel or chilled iron. The frog may be made of cast iron, malleable iron or forged steel. The beam is usually made of bessemer steel or wood. The shin, point and heel of landside are usually reinforced by welding a patch of steel on the part or by making it an interchangeable part.

The entire plow detached from the beam is often spoken of as the plow bottom. The varying conditions in which ground is to be plowed has caused the establishment of a few general types of plow bottoms, each with its form of moldboard and share. These forms are illustrated in Fig. 512, and vary from the long, sloping share and moldboard for the breaker for the natural sods, to the short, abrupt curvature of the old ground or stubble plow. The intermediate forms may be used for the sod of the cultivated grasses or for stubble ground, and hence are given the name of general-purpose plows. Sulky plows are now usually made with interchangeable bottoms. Some manufacturers build plows with interchangeable moldboards and share; thus the same plow may be used in a variety of soils. (Fig. 513.) The stubble plow has more of a pulverizing action, the abrupt curvature of the moldboard causing the furrow-slice to be broken up and crumpled in making the sharp turn.

The jointer is used when the soil is inclined to be soddy. It throws a ribbon-like strip of turf into the furrow and enables the plow to do cleaner work and to cover the stubble and other vegetation deeper. When sod ground is to be plowed deep and left in shape for immediate pulverizing so as to fit it for crops, this tool will often render excellent service by cutting out a section of the sod, turning it into the bottom of the furrow where it will be completely covered, at the same time leaving the upper edge of the furrow-slice composed only of comparatively loose or broken earth. A common form of jointer is illustrated in Fig. 514.

Fig. 521. The modern disc plow, made for horse power.

By the "set" of a plow is meant the proper adjustment of the point, share and beam so as to insure proper running. The original set is given to the plow by the maker, and each time the share is sharpened the smith is depended on to return this set to the plow. By "suction" is meant the amount the point is turned down to secure penetration. In actual measurements the suction is the width of the opening between the landside and a straight-edge laid on it. (Fig. 515.) In sulky plows the suction is the amount the heel of the landside lacks of touching when the share is flat on a floor. In walking plows the suction is usually about one-eighth inch, and in the sulky plow it is about one-half inch.

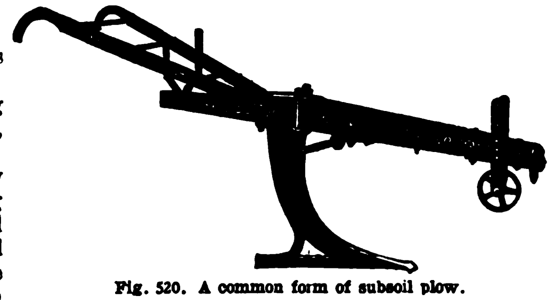


Fig. 520. A common form of subsoil plow.

The beam of a two-horse plow is usually set a little to the side of the line of the landside, in order to place the hitch more directly behind the team. The amount varies, but is usually about three inches. With three horses the beam is in line with the landside. The point of the beam for ordinary plows stands 14 inches high. For hard soils this is sometimes increased. In walking plows some bearing must be given at the heel of the share to carry the downward pressure of the furrow. (Fig. 516.) The amount of this bearing is usually about 1 inch in width for 12- and 14-inch plows, and 1½ inch for 16-inch plows. More bearing should be provided for soft, mellow soils than for the more firm soils. Thus the same plow will not work well or will swing to one side or the other in changing from hard to mellow soils. A device called the heel-plate is used on some plows to vary the width of surface at the heel. (Fig. 517.) With sulky plows no bearing surface at all is given, because the wheels have the downward pressure to carry.

The rolling coulter should be set to clear the shin of the plow by about one-fourth inch. It should cut about one-half inch or three-fourths inch outside of the shin. It is sometimes easier to make a plow scour by making the coulter cut an inch or more outside of the landside, increasing the load on the plow.

Poor scouring of a plow may be due to several things. (1) Poor temper. If the share and moldboard are not properly tempered they will not take a good polish and hence will not scour well. These parts should be so hard that it is impossible to scratch them with a file. (2) Poor grinding. Sometimes plows have holes ground into them, and in these spots the soil sticks and they will not scour. This can usually be tested by placing the tips of the fingers at the edge of the share and carrying them up the plow quickly in the path the soil moves. (3) A plow will not scour if it is not well fitted—that is, if the joint between the share and moldboard is not smooth. This can be remedied by shimmering the share up or down by a small piece of pasteboard. (4) Plows sometimes do not scour because the edge of the share is not level. The remedy for this is known without stating.

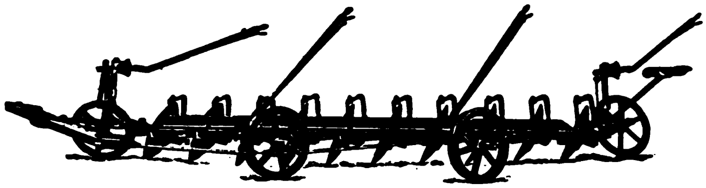


Fig. 522. Disc engine gang.

Hillside or reversible plows are required in localities where it is too sloping to throw the furrow up hill. Figs. 518 and 519 illustrate this type of plow. Reversible plows are also used in irrigated districts where dead furrows interfere with the carrying of water on the land.

Subsoil plows are used in loosening the ground to a greater depth than can readily be done with the surface plow. The subsoil plow is used at the same time as the regular plow, following in the furrow made by it. Fig. 520 is a common form of this plow. There is some difference of opinion in regard to the value of the subsoil plow, but it is not the object of this paper to discuss the question.

Plowing by steam has been attempted for many years, but it was not until recently that it became very successful. When power of this kind is used for other purposes, and when farming is conducted extensively, plowing can no doubt be done at a saving over the use of horse-power. The use of the steam plow is limited at present to large farms and to level land. It is also impossible to use the steam plow when the soil is not firm, for the great weight on the traction wheels causes them to sink in soft ground until they are unable to pull the plows.

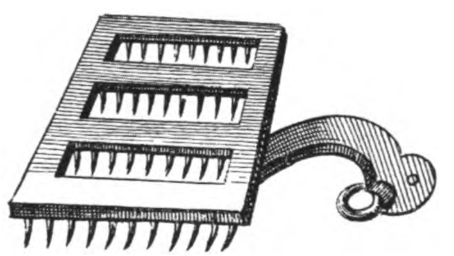


Fig. 523. An English harrow of two centuries ago. 'A Figure of the Harrow most commonly used, to be drawn over plough'd Grounds by Horses, for levelling and burying of Grain. Sometimes two of these are drawn together over a Field. Besides this Sort, it is common to harrow very light Soils with Bushes, or Bundles of Thorns, especially where Seeds require to be slightly cover'd."—Bradley, Survey of the Ancient Husbandry and Gardening. 1725.

The advantages of the steam plow are, first, its capacity, and second, unlimited power, permitting greater depth of plowing. Plowing outfits are now in use capable of plowing 40 to 60 acres in a day, and at the same time preparing the seed-bed and seeding it. In certain soils it is beneficial to plow occasionally to a greater depth than can be done easily by horse-power. The steam plow is able to do this and may, in some cases, be the means of producing a greater yield of crops. The power outfits carry large gangs of plows, sixteen to twenty being not uncommon. In Europe, plows are sometimes drawn by cables worked from an engine at the end of the field.

Disc plows.—The disc plow was produced through the efforts of inventors to reduce the draft due to the sliding friction on the moldboard. About the first patent was granted to M. A. and I. M. Cravath, of Bloomington, Ill. This plow consisted of three discs cutting very narrow strips, and it is said to have done satisfactory work under certain conditions, but did not have sufficient means of relieving the side pressure. Among the promoters of the disc plow, the name of M. T. Hancock is prominent. He succeeded in introducing the disc plow into localities where the conditions were well-adapted for its use. Figs. 521 and 522 illustrate the modern disc plows as made for horse or engine power.

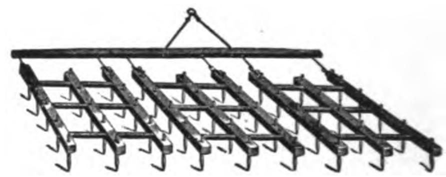


Fig. 524. Smoothing harrow with wood frame.

In soils where the moldboard plow will do good work there is nothing to be gained in the use of the disc plow. The draft is more often heavier for the amount of work done and the plow itself is more clumsy than the other form. However, in sticky soils where the moldboard plow will not scour, the disc plow can often be made to do good work. Again, in very hard ground where it is impossible to plow with the moldboard plow, the disc will work and apparently with much less draft. The manufacturers of both disc and moldboard plows are now recommending generally the use of the latter for soils where it does good work.

Within the past few years disc plows have been presented to the trade in the walking style of plow. As a rule, they have not proved very satisfactory. A few plows of this style are made reversible for hillside and irrigation work.

Draft.—The draft of a plow varies greatly with conditions,—the nature of soil, root growth and amount of moisture present. It varies also with the shape of moldboard: the more abrupt the curve of the moldboard the more pulverizing the action on the furrow-slice, and hence the more work done.

Professor King gives the following table of results of trials of draft made by Mr. Pusey, of England, and others in America:

Kind of soil	No. of plows	Size of furrow	Total draft	Draft per sq. in. of furrow
Loaming sand	10	5 x 9 in.	250	5.55
Sandy loam	10	5 x 9 in.	280	6.22
Moor soil	10	5 x 9 in.	440	9.72
Strong loam	10	5 x 9 in.	661	14.69
Blue clay	5	6 x 9 in.	566	10.48
Sandy loam (J. C. Morton) .	14	7 x 10 in.	407	5.81
Stiff clay loam (N. Y. 1850).	10	5 x 9 in.	227	5.04

Following are results of a test of draft made at the University of Illinois with a 14-inch plow, known as the "Scotch Clipper":

Test	Depth	Width	Sq. in. in furrow	Total draft	Draft per sq. in.
A . . .	7	10.9	76.3	293.9	3.85
B . . .	7	11.47	80.29	290.56	3.61
C . . .	7	14.04	98.23	363.87	3.70
D . . .	7	17.74	124.18	445.19	3.58

From a long series of tests, the following conclusions were drawn:

(1) Plows of the same width of furrow have more draft per square inch of cross-section of furrow as the depth increases.

(2) Plows of the same depth of furrow have more draft per square inch as they increase in width.

It is generally asserted that the draft of sulky plows is less than that of walking plows, because the friction of the sole and landside is transferred to the well-oiled bearings of the carriage. From records obtainable there is no gain shown, however, when the weight of the driver and of the frame of the plow is not deducted. If the draft is but little greater on the team with the man riding than when walking, and the plow can be handled with equal facility, there is an evident advantage in riding plows. [Draft of plows is also discussed on p. 204; see Fig. 228. Other opinions on plows will also be found at that place.]

Draft tests seem to indicate that there is very little difference between sulky and gang plows per square inch of furrow. The results of the following tests made at Iowa State College bear out this statement:

	Size of furrow	Total draft	Draft per sq. in.
Gang plows . .	14 x 5 x 2 in.	700 lbs.	5 lbs.
Sulky plows . .	16 x 6 in.	474 lbs.	4.93 lbs.
Walking plows .	14 x 6.5 in.	440 lbs.	4.83 lbs.

Adjusting the plow.— In the operation of plows only a few points need be observed. With walking plows, the tool should take care of itself as nearly as possible, the plowman needing only to steady it with the handles. If it requires a steady pull to one side or to the other, the plow should be adjusted. Either the amount of bearing given at the heel or wing of the share is too much or not enough, or the hitch or clevis should be adjusted. With three-wheel sulky and gang plows the land wheel should travel directly to the front. When the plow is in bad adjustment this wheel is often required to slip occasionally, because it is traveling at an angle with the direction of the movement of the plow. The rear furrow-wheel is usually turned out a little from the unplowed land or, as it is generally stated, is given a small amount of "lead" from the land. The wheel should also set an inch or so outside of the line of the landside so as to remove the friction on this part as much as possible. The front furrow-wheel is given "lead" from the land with the single plow and toward the land when the team is hitched abreast on gangs. The change is made in the latter case because the line of draft is outside of the line of work, and hence the front furrow-wheel is turned in to hold the plow out to its work and make it travel directly to the front.

With all wheel plows, as much of the load as possible should be carried on the wheels in order to reduce draft. The draft should be reduced when the downward pressure due to lifting the furrow-slice, and the landside pressure due to turning it, is carried on wheels with well-lubricated bearings rather than on the sole and landside of the plow.

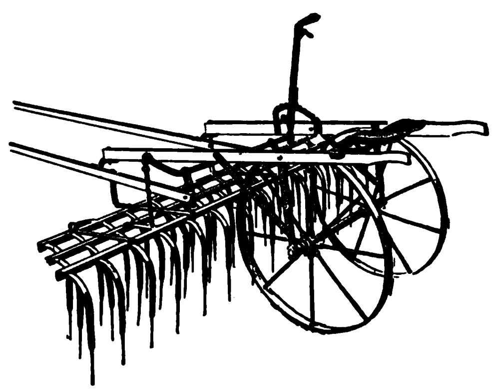


Fig. 526. A weeder, that will do excellent work in killing young weeds.

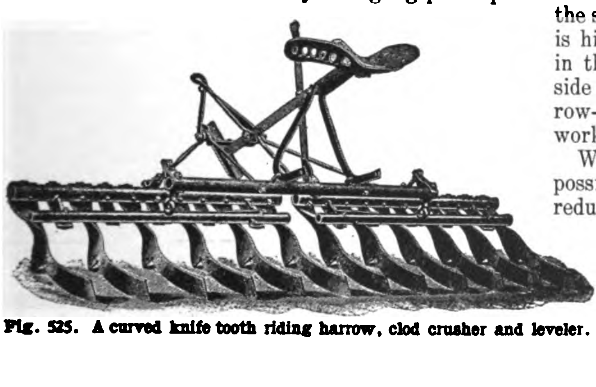


Fig. 525. A curved knife tooth riding harrow, clod crusher and leveler.

With the walking plow, the center of the point of the beam on the average is about fourteen inches from the floor when the plow is flat. In wheel plows this is often more. Disc plows are often provided with a spring hitch which springs down and has a tendency to hold the plow down. Nearly all the later models of sulky plows have a direct beam hitch, and the plow frame is attached to the plow beam and is drawn by it rather than having the frame draw the plow. This has proved to be the most desirable construction. The cutting edge of the share should always be kept sharp, for experiments have shown that a large proportion of the draft is due to the cutting of the furrow-slice. The cutting edge will be retained longer if the share, after being heated to be sharpened, is hardened again.

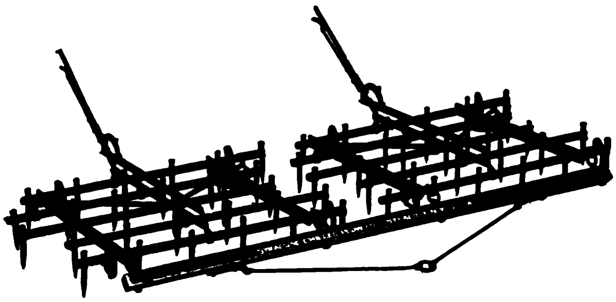


Fig. 527. Lever harrow. A variable pitch can be given to the teeth.

In sulky plows the point should always be set well down. In the sulky plow the entire load should be carried on the wheels. This is true also of the landside pressure. The front and rear furrow wheels are set on an incline for this reason. The edge of the rear furrow wheel is set about 1¼ inches inside of the line of the landside. Landsides on sulky plows should be more of an extra than a necessity.

With sulky plows some provision should be made for plowing among rocks. The plow should be so fixed that it will "float." A sulky plow will throw the rider very hard if such provision is not made.

In hitching the team, the animals should not be spread too much or crowded too much, for in either case good work cannot be done. When spread too much, the team will not travel directly to the front and the line of draft will be too far out to do good work. When crowded, the horses work at a disadvantage and will heat quicker in warm weather.

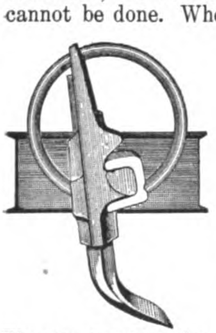


Fig. 528. Combination spring and cultivator harrow tooth.

Plows require very little care, as they are not very complicated. The wheel bearings are now provided with magazine wheel boxes which are dust-proof and are closed at the outer end, and which carry a supply of grease to last for a long time. The polished surface of the plow over which the soil is required to pass should be protected from rust when not in use. A coat of heavy grease or "axle grease" will do this effectually. Like all other implements, it should be housed out of the weather when not in use.

The harrow.

The tool which usually follows the plow in the course of tillage is the harrow, or drag. With the exception of the plow, the harrow is perhaps the oldest of the tillage implements. It is used in pulverizing and smoothing the surface preparatory to seeding, and for killing weeds at a time when they are starting to grow.

The first harrow was, no doubt, the limb of a tree with extending branches. The limb selected was of a size to suit the man or animal power to be used, and with nearly all of the small branches lying on one side or the other so that the entire branch would lie flat when used. The first type of harrow developed from this and consisted of a forked limb with spikes in each arm. Later a cross-arm was attached and the implement was known as the "A" harrow. The Romans devised a kind of square or oblong harrow, made with cross-bars with many teeth in them. This type of harrow remained the standard until late in the sixteenth century. An old English harrow is shown in Fig. 523.

Fig. 529. Spring tooth harrow, well-fitted for work in rough and stony ground. Within the present generation this implement has come to be a standard.

Harrows may be classified as follows for the purposes of this article:

(1) Tooth harrows, known as pulverizing and smoothing harrows.
- Straight fixed tooth.
- Adjustable tooth.
- Curved tooth, pulverizers.
- Spring tooth, weeders.

(2a) Lever harrows.
- Straight tooth.
- Cultivator tooth.
- Spring tooth.
- Combination spring and spike tooth.

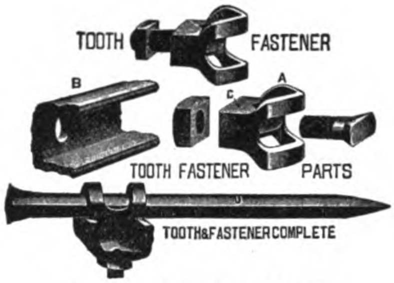


Fig. 530. Harrow tooth fasteners.

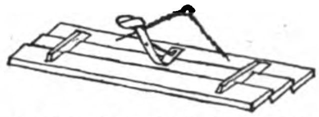


Fig. 532. A serviceable planker that is easily made on the farm.

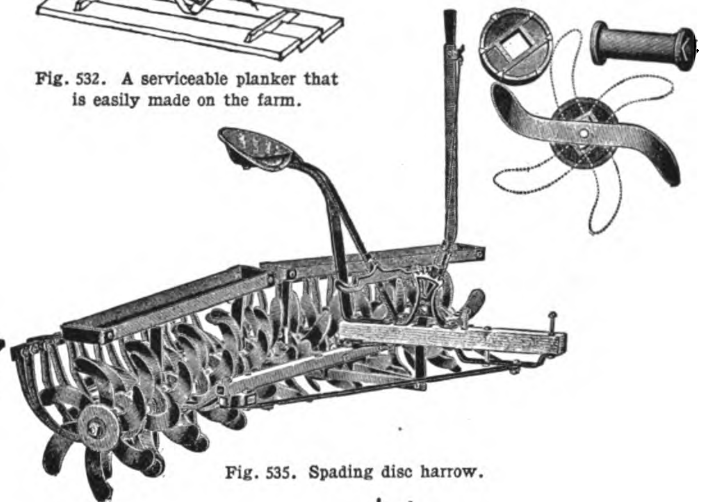


Fig. 535. Spading disc harrow.

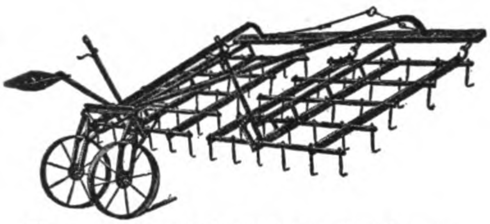


Fig. 531. Riding attachment for smoothing harrow.

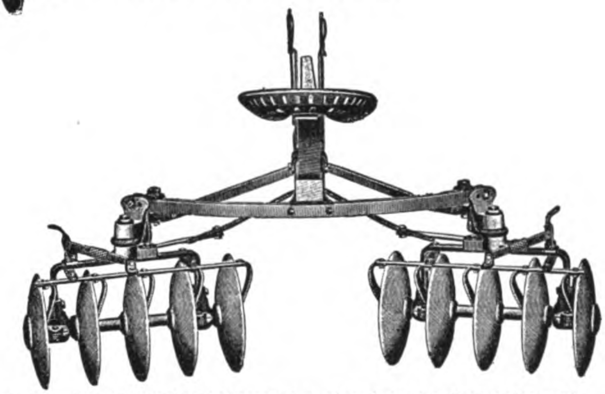


Fig. 536. The orchard disc harrow, showing wide frame for work under trees.

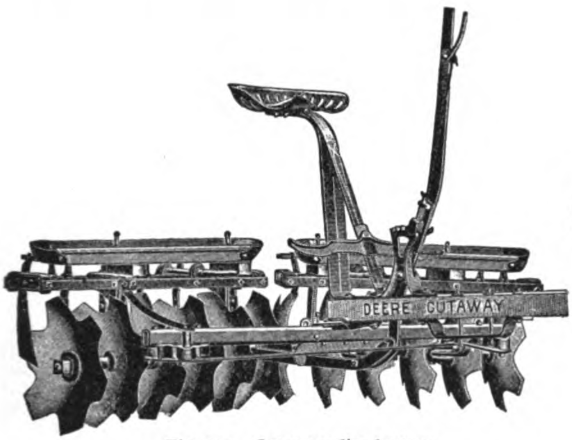


Fig. 534. Cutaway disc harrow.

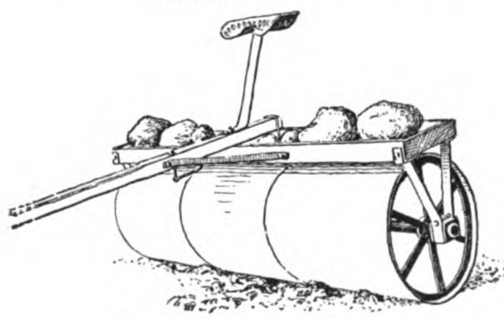


Fig. 537. The smooth iron roller.

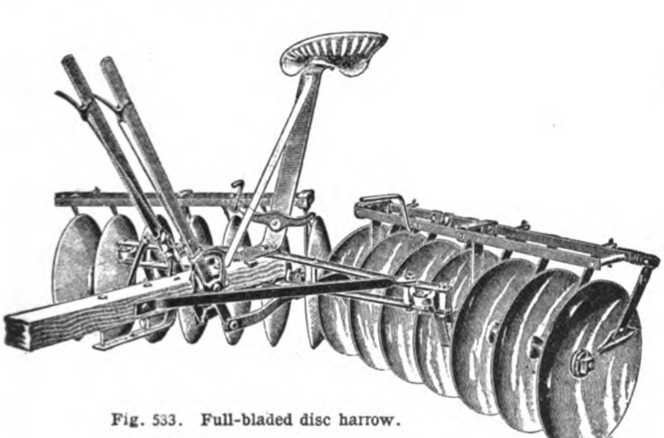


Fig. 533. Full-bladed disc harrow.

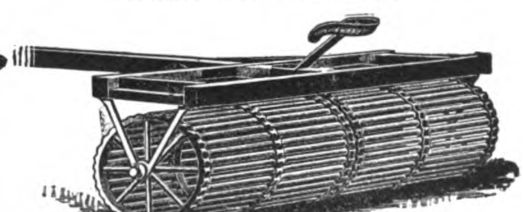


Fig. 538. Corrugated roller.

(2*b*) According to styles of frames.
Wood frame.
Pipe frame.
Channel or U-bar frame.
(3) Disc harrows.
Full disc.
Cutaway.
Spading.
Orchard.

It will be impossible to illustrate all these various forms of harrows. Fig. 524 shows a common smoothing harrow with wood frame. This harrow often has a tooth fastener so arranged that when drawn from one end the teeth will slope backward and can be used in trashy ground to better advantage. Such a tooth may be said to be adjustable. In Fig. 525 is shown a curved knife tooth harrow, sometimes called a pulverizer, which will do excellent work in crushing clods and bring the soil into a more uniform structure. A weeder, as shown in Fig. 526, will do excellent work in killing weeds as they are beginning to grow. Lever harrows are now made that will give a variable pitch to almost any kind of tooth. Fig. 527 illustrates the common style of tooth. Fig. 528 gives the cultivator tooth in combination with a spring. The spring-tooth harrow, illustrated in Fig. 529, is a tool that is especially well fitted to work in rough and stony ground; the teeth, when caught on an obstacle, spring back and are released. It also has great pulverizing power.

Harrow frames were formerly made almost entirely of wood. Of later years, however, steel pipe and channel bars have been used. Fig. 530 shows a method of fastening the tooth to the bar. The fastener is an important feature of the harrow and should always be examined when a purchase is made. The teeth should always have heads on them, so that when the fastener for any reason becomes loosened the tooth will not be lost. The connection between the sections of the harrow and the evener should be looked into, as more often this is the first part to wear out.

In Fig. 531 is shown a harrow cart that is placed behind the harrow in order that the operator may ride. Attachment is made to the eveners by angle bars and the wheels are made to caster, so as to follow the harrow in turning. The wheels should have wide tires in order that they will not cut too deeply into the soft soil. Walking behind a harrow on the soft ground is very laborious, and the harrow cart makes the work much easier; at the same time the rider is above the dust and has perfect control over his team. The extra amount of draft should not be very much.

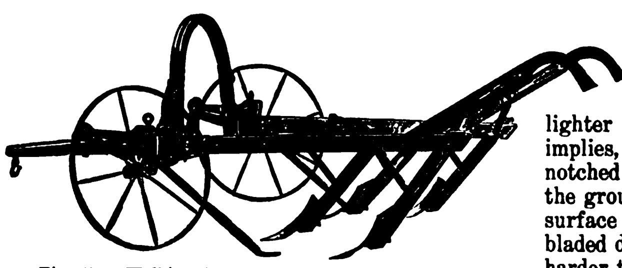


Fig. 539. Walking four-shovel tongueless cultivator.

The common planker, as shown in Fig. 532, is a tool that is very useful in crushing clods and smoothing the surface It has, perhaps, a better pulverizing effect than the roller, as the sliding action tends to catch the clods and break them, while the roller tends to push them into the soft soil without crushing them. However, it does not have the packing effect of the roller. It is generally a home-made tool. One disadvantage of this tool is that it will not adapt itself to the unevenness of the surface.

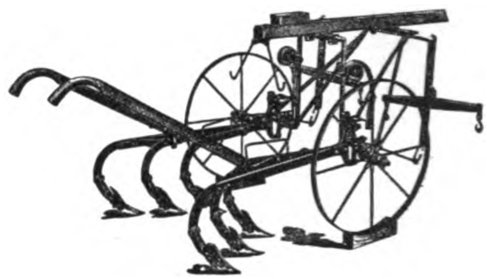


Fig. 540. Walking six-shovel cultivator with tongue.

The disc harrow is perhaps the most effective tool yet devised to pulverize and loosen the surface of the ground. Its rolling action adapts it to a great variety of conditions. It may be used for loosening the soil or pulverizing it, and can be used to advantage in reducing plowed ground that is inclined to be soddy. It may be used even on hard and dry soil to prepare it for plowing. It is also a useful tool in destroying weeds when they have made too great a start for the smoothing harrow. The disc harrow has a place on every farm.

In Figs. 533, 534 and 535 are shown respectively the full disc, cutaway and spading types of disc harrows. The full-bladed disc has the greatest pulverizing effect and also has the advantage of being more easily sharpened when dull. The edge may be ground or turned. The diameter of the discs ranges from 12 to 20 inches. The medium-sized, or 14-inch, seems to be the size best adapted to all kinds of work. The larger sizes, however, may be of slightly lighter draft. The cutaway disc, as the name implies, has sections of the periphery of the blade notched out. The remaining sections may penetrate the ground to a greater depth, but not all of the surface is as thoroughly pulverized as with the full-bladed disc. It also has the disadvantage of being harder to sharpen. The spading harrow has blades curved at the ends so as to form a sort of a sprocket wheel with cutting edges out. It works much like the cutaway and can be sharpened only by separating the blades and drawing them out much as a plowshare is sharpened. In Fig. 536 is illustrated the orchard disc, which differs from the common disc only in having a wide frame so that work may be done under the branches of trees.

The disc can often be set to throw in or out from the center to suit the nature of the work.

The bearings of the disc harrow are the parts that are usually first to wear out. Various styles of ball-bearings and chilled iron bearings are now to be found on the market. None seem to be more satisfactory than one made of hard wood, for the reason that it can be easily replaced. All bearings should be carefully protected from dirt.

Another important feature of the disc harrow is the scrapers or cleaners which keep the discs clean. These may be made stationary or to be operated, when needed, by the feet of the driver or otherwise. The latter method is preferred, as they are needed only occasionally when wet, and the former method produces an undue amount of friction. An automatic cleaner is made to oscillate by horse-power back and forth over the face of the disc blade once in every six revolutions. It also can be thrown out of gear when not needed.

The roller.

The land roller is used to smooth and firm the ground, and is very efficient in working up a fine

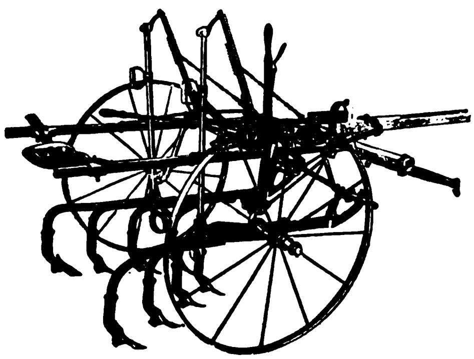


Fig. 541. Riding cultivator with eight shovels, showing hammock seat and balance frame.

tilth. The first rollers were made by the selection of a proper log, in the ends of which pins were inserted and a yoke provided to draw it. This implement was common a generation ago. The single section was found to be cumbersome in turning, and did not work well on uneven ground when made of any width. This led to the introduction of rollers made in two and three sections. The smooth roller is illustrated in Fig. 537. As this implement smooths and packs the ground, it permits the capillary water of the soil to escape into the air. If the soil moisture is to be conserved, the rollers should be followed with a smoothing harrow to put a dust-mulch over the surface, and, by roughing it, lessen the wind velocity. The roller leaves the ground in much better condition to be followed by mowers or other machines.

Several styles of corrugated and ribbed-surfaced rollers have been invented which are said to have certain advantages over the plain smooth roller, inasmuch as they crush the clods better and do not leave such a smooth surface. One of this type of roller is illustrated in Fig. 538. A tool of this nature was invented by H. W. Campbell, to pack the ground beneath the surface. This tool is called the sub-surface packer (Fig. 545), and consists of a series of wheels with wedge-shaped tread.

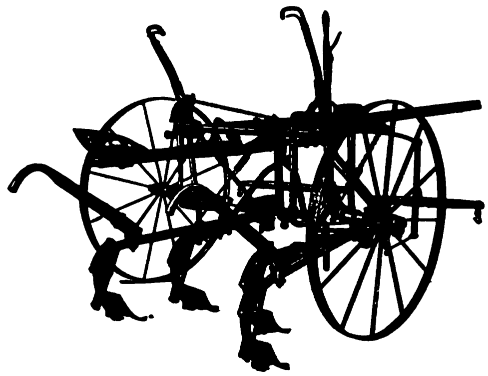


Fig. 542. A combined cultivator, the driver walks or rides.

It is stated by an authority that rollers should not weigh more than 100 pounds per foot of width, and should not be less than 2 feet in diameter. The roller is, without doubt, a very important tool when used intelligently.

The cultivator.

Next in order comes the cultivator. The first cultivator was a kind of crude hoe that has been developed, under the addition of animal power, until we have machines that are indispensable to the cultivation of growing plants. The primitive single-shovel gave way to the double-shovel. The double-shovel was supplanted by the straddle-row cultivator, and even the latter has been doubled until in some cases it is adapted to take two rows at a time. Early in the eighteenth century, Jethro Tull invented a horse-hoe and drill, but his machine never became popular. The double shovels used in this country until the year 1860 were made generally by country blacksmiths. George Esterly took

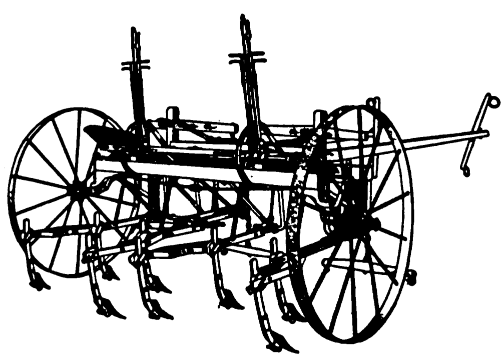


Fig. 543. Two-row cultivator.

out a patent on a straddle-row cultivator for two horses, April 22, 1856; this was the first of the line of implements in the manufacture of which millions of dollars are now invested.

It will be impossible to describe or illustrate all the various types of cultivators found on the market. The simplest of them all, omitting the single and double shovel cultivators, is the four-shovel walking tongueless cultivator, similar to the one illustrated in Fig. 539. This is a cheap tool and has an advantage in requiring little space for turning at the ends of the rows. To do good work with this kind of cultivator, it is necessary for the team to work very evenly.

The cultivator in Fig. 540 shows a tongue and also is provided with six teeth or shovels. Fig. 541 illustrates a good type of riding cultivator. This

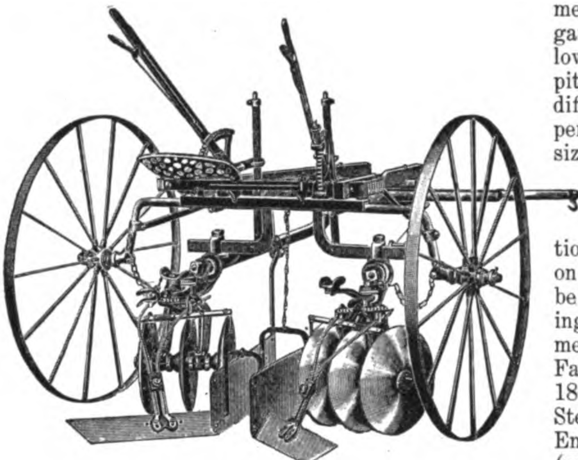


Fig. 544. The disc cultivator.

cultivator is provided with a hammock seat which is hung from the sides of the frame, a pivotal tongue which enables the cultivator to be adjusted for hillside work or when it is not desired to have the cultivator follow the team, a balance frame that adjusts the weight of rider and frame on the wheels, and gangs with eight shovels placed obliquely. The pivotal tongue is made use of in some cultivators as a steering device.

The gangs of a cultivator include the shovels, shovel legs or shanks, and the beam. Most manufacturers are able to equip their cultivators with any style of gang with four, six or eight shovels. The eight-shovel gangs may have the four shovels of each side set obliquely or have one shovel follow between the two leading ones, in which case it is termed an "eagle claw." The teeth or shovels may be supported with springs, and in this case are said to be spring-tooth. The six- and eight-shovel gangs are the more desirable from the standpoint of the work they do, but are more difficult to handle in trashy ground.

In Fig. 542 is illustrated a cultivator that permits the operator to walk or to ride, and hence it is called "combined." This cultivator is also provided with a spring trip to the shanks or shovel legs which permits the shovel to pass over any obstruction it may encounter and to return to place. The usual safety device is a wood pin, which, when broken, permits the shovel to swing back. This cultivator is also provided with a straddle seat.

The gopher cultivator is used for shallow or surface cultivation and is very useful in clearing the ground of certain kinds of weeds and to conserve the moisture by making a soil-mulch. Perhaps the latest development in cultivators is the two-row cultivator shown in Fig. 543. This is a very useful tool when farm labor is scarce, and is said to do very creditable work on subsequent cultivations. The disc cultivator, Fig. 544, is a good tool to cover large weeds and to move a large amount of soil in one direction.

In general, all cultivators should have a wide range of adjustment. They should permit of adjustment in the width of track, width between the gang, and permit the front ends to be raised or lowered to regulate depth of the front shovel. The pitch of the shovel should be adjustable for the different conditions to be met, and the hitch should permit of raising or lowering to suit the different size of horses.

Literature.

The reader may consult the following publications for further information. Most of the writings on this subject are old. The trade literature will be found most helpful: Text-book of Farm Engineering, by John Scott (Chapters I to IX), Field Implements and Machinery, 1885; Farm Implements and Farm Machinery, by J. J. Thomas (pp. 115–152), 1869, New York; The Book of the Farm, by Henry Stephens (Vol. I, pp. 85–121), 1891; American Encyclopedia of Agriculture, by Jonathan Periam (pp. 739 to 750), 1881; Morton's Cyclopedia of Agriculture, (Ploughs, Vol. II, pp. 628–650); Physics of Agriculture, by F. H. King (pp. 221–254), 1901, Madison; Fertility of the Land, by I. P. Roberts (Chapter II), 1897.

A SYSTEM OF SCIENTIFIC SOIL CULTURE FOR SEMI-ARID REGIONS

By *H. W. Campbell*

One of the applications of most far-reaching importance in the history of agricultural investigation is what is known as "scientific soil culture," or the proper handling of the soil under semi-arid conditions. This method of soil treatment has been evolved through many years of careful and persistent study. It is only by a careful study of the soil and of nature's methods of treatment that the farmer can come to know the what, how and when indispensable to successful farming.

The beginnings of "scientific soil culture."

The system known as "Campbell's system of soil culture" has been the outgrowth of the writer's own experience and investigation. In 1879 he settled, with others, on the fertile prairies of James river valley, in what was then the territory of Dakota, and began raising wheat. The failure, in 1883, of most of his crop grown on fall-plowed ground, and the success of the crop on the spring-plowed ground, led him to think that fall plowing was inadvisable, and as a result he did very little plowing that fall. The next season, however, produced just the opposite results, and the crop on the fall-plowed land was the better. He immediately set out to determine why.

It was commonly stated at that time that the failure of crops was due to soil depletion, that the early large crops had exhausted the soils so that they would never produce again. By reading the available literature on soils and crop-growing, the writer soon became convinced of the falsity of this notion. He found that Jethro Tull had seen crops growing successfully in Italy and France on land that had been under cultivation for many years, and that Tull himself had grown thirteen unmanured wheat crops without intermission and without decrease of yield, on the same field, by applying adequate tillage. These facts, together with similar results secured by many others, led the writer to investigate the problem of soil culture, and the importance of tillage as a substitute for manures. Much assistance was gained from the results of similar experiments made by Rev. Samuel Smith in Northamptonshire, by Mr. Terry, of Ohio, and by the Cornell University Agricultural Experiment Station.

It was not until 1892, after eight years of experimenting, that any very tangible results were secured. About this time, the reports of the investigations of Professors King and Goff of Wisconsin, Hilgard of California, Bailey and Roberts of New York, and others, with reference to soil moisture and its movements, came to hand and aided materially in shaping the work which is reorganizing agriculture in the great semi-arid West. This system has recently been termed "dry-farming," a name that is somewhat misleading, as it indicates that plants grown by the method require less water than others, which is not true. The fact is, more water is used in growing a crop by this method under semi-arid conditions than is used for an ordinary crop by the common systems in sections of greater rainfall because a much greater percentage of the water is utilized.

In the early part of the work the writer had noticed, especially in the drier seasons, the very marked effect from the compact condition of the soil where a horse had stepped on plowed fields, afterward sown to small grain, and where heavy farm wagon wheels had rolled over the field—that the grain was always taller, of a darker, healthier color, wider leaves, giving a greater stooling, and with longer, better filled heads. The observance of the fact that the lower part of the furrow-slice was made fine and firm while the top was loose in all the places where the grain had made the marked growth above referred to, was unquestionably the prime cause of the writer's investigation. The loose top was the dirt that had fallen in as the horse lifted his foot, or by the lifting of the rear part of the wagon wheel out of the track in its forward motion. If only the loose surface and not the compacted stratum, or the firming and not the loose surface had been recognized, the marked results given below would not have been achieved. These two conditions are highly important in farming in the semi-arid sections.

Observation has shown that the more arid the section the greater the percentage of vegetable matter that is partially or slightly decomposed in what are commonly termed sandy loam soils,—those that predominate over the high level prairies of the great semi-arid West. The soils of these prairies in their virgin state are rather firm, probably due in part to the fact that millions of buffaloes have tramped over them for ages. This is one reason why the early settlers almost invariably secured their best crops from newly broken lands. The average precipitation in this belt is lightest in the late fall, winter and early spring. The fields were plowed in the spring when dry, and this was a waste of time, as dry soils will not pulverize and settle down to form a fine, firm root-bed. The early settlers disregarded the storage and conservation of moisture. That these prairie soils are liberally supplied with vegetable matter, and plowed mainly when dry, accounts for the fact that the plowed fields become so much lighter and looser each succeeding year.

The early attempts to increase production.

In the early efforts to increase the yield, a subsurface packer was devised and built. The purpose was to imitate the effect of the horse-foot track in the entire field, that of firming the lower part of the furrow-slice and leaving the top loose. This was accomplished only after much experimenting. The packer shown in Fig. 545 was the sixth attempt. The wheels of this machine are eighteen inches in diameter, the rim one inch thick at the inner part, beveled two and a half inches to a sharp outer edge, and placed on a shaft, five inches apart

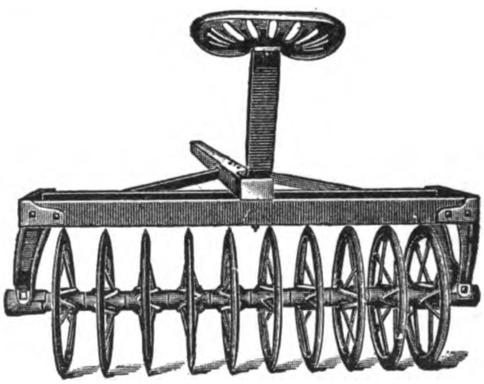


Fig. 545. Campbell's subsurface packer.

on centers. The effect, as it rolls over the ground with about 500 pounds of weight added, is the same as crowding a one-inch wedge into every five inches of soil, giving a lateral and a downward pressure, packing firmly the lower part, as shown in Fig. 548.

The next step was to devise and build a drill to plant six rows of small grain twenty inches apart (Fig. 546), and a cultivator to work the six rows at one time (Fig. 547). A number of these machines were built and used. Two ordinary horses did the work with each machine successfully.

Some very marked results were secured at several points in Nebraska and North Dakota in 1896, a dry year. In an experiment at Lisbon, North Dakota, the yield of wheat by the inter-cultural method from twenty pounds of seed per acre was 27½ bushels; from one-half bushel of barley, 54¼ bushels; from three-fourths of a bushel of oats, 82 bushels. These fields were cultivated six to eight times, depending on conditions. By the ordinary methods, the same year, 1½ bushels of wheat seed, as commonly sown per acre, yielded 3 to 7 bushels; 2 bushels of barley seed yielded 6 to 15 bushels, and 2½ bushels of oats seed yielded 0 to 20 bushels per acre.

While the results of this method were very satisfactory, there were yet two strong objections by the average farmer: (1) The new and expensive machinery required, (2) the large amount of team work and labor required for the big farming enterprises then so prevalent. The method was abandoned, partly for these reasons, but mainly because of an accidental demonstration of the value of continued tillage of a field one entire season; more recent developments, however, indicate the method worthy of further consideration.

In 1898 a field had been carefully fitted and planted with the special drill to spring wheat. In June, when it was about fifteen inches high, a severe hail-storm ruined the crop. In a day or two this field was twice gone over with a disc harrow, and kept tilled the remainder of the season after each rain, and a sufficient number of other times to prevent any weeds growing. It was then seeded in late September to winter wheat with a common shoe drill, 45 pounds of seed per acre being used. Much wheat was winter-killed that year, and the spring of 1899 was very dry. This wheat, however, did not winter-kill, the entire field carried a dark green color all winter, and as soon as the soil

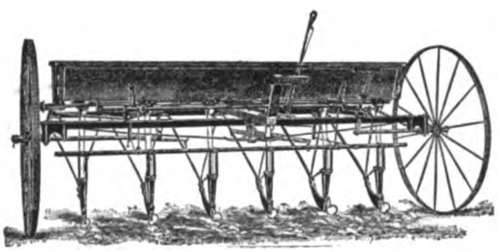


Fig. 546. The Campbell combined cultivator and grain drill.

became sufficiently warm it began to grow and tiller, having the appearance of a highly fertilized field. The grain stood so very thick and rank that an ordinarily heavy storm just after heading laid it flat on the ground, and not more than half of the grain could be harvested. But it prompted a line of investigation to ascertain why this marvelous growth had occurred.

Summer culture.

Through the medium of summer culture, large crops are now grown in the most unfavorable seasons in the semi-arid sections. When it comes to be scientifically applied, that once conceded worthless country will be a desirable general farming section, where large crops will be grown annually in spite of the adverse climatic conditions. The writer and his associates are now in the seventh

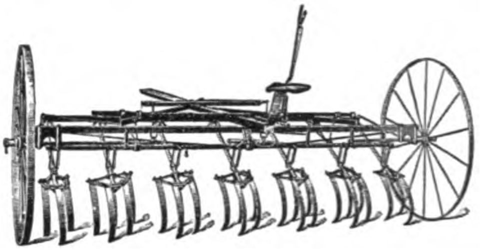


Fig. 547. The Campbell surface cultivator, as used in cultivating six rows of small grain.

year of their experimenting to ascertain the effect of summer culture, and have plans for four years more to prove more fully its worth.

This work was begun in western Kansas, under twenty inches of average annual rainfall. The first method was to alternate summer culture with a crop, and then proceed under the following system of fitting, which it has not been found advisable to change: If the field is old ground, as soon as the frost is out in the spring, and the soil sufficiently dry so as not to stick to the disc harrow, the field is double-disked by lapping one-half. By this lapping the surface is thoroughly loosened and kept level, as the outside disc the second time over fills the dead furrow left by the center in its preceding trip. This loosening to the depth of approximately three inches, brings about two most desirable conditions: A loose mulch to prevent the loss by evaporation of any moisture that may be in the soil, and the opening of the surface, which permits a much greater proportion of the next rain to percolate into the subsoil. After a rain of any considerable amount, the field must be gone over again as soon as the surface is dry enough to permit working. The kind of tool for each subsequent cultivation must depend on the quantity of the rainfall and the quantity of weeds, stubble and the like, on the surface. This tilling should continue until late June or early July, after each rain and sufficiently often to keep the weeds from growing.

Then comes the plowing, which should be done to a depth of fully seven inches. In the field treated as above specified, the soil will be moist, and when turned over by the plow will readily pulverize. The surface being fine, there are no clods to turn to the bottom of the furrow. The sub-surface packer must now be used while the soil is still moist, and the lower half of the furrow will become thoroughly fined and firmed. As closely as possible the packer should be followed with the harrow, weighted, and with the teeth slanting back; this will pack a part of the soil not firmed by the packer, and will break the surface clods finer, forming an even mulch, provided too much time has not elapsed between the plowing, packing and harrowing. From this time the field must be cultivated after every rain and often enough to

Plate XXI. The plowing and the harvest on the plains. The upper picture is taken in the Canadian Northwest, the lower in Dakota prevent any weeds growing. It is then seeded to wheat in the fall or left for a spring crop.

The old notion of allowing the weeds to grow to be turned under as a fertilizer, as commonly practiced by the old summer fallow system, will never do in this section. The following experiment was made by the writer to demonstrate this point: A piece of

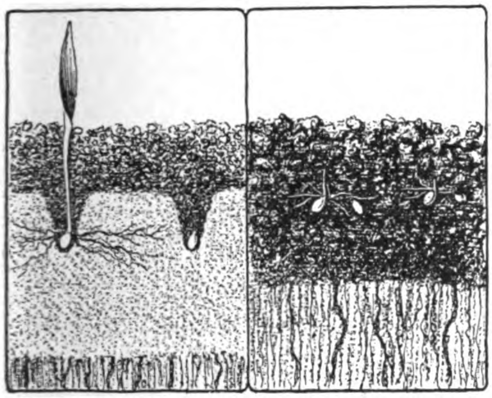


Fig. 548. Germination of wheat influenced by firmness of soil.

ground was summer-tilled in 1903, and sowed to winter wheat, 25 pounds per acre. The crop was cut June 29, 1904, yielding 48 bushels. The crop was removed and the field double-disked. July 14th and 15th a strip 4 rods wide was plowed around the outside and the plow followed closely with the packer and the harrow. The field was then untouched for five weeks, and a thick growth of weeds came up on the unplowed part. Very little rain fell during this period. The remainder of the field was then plowed, and the weeds turned under. It was then given the regular packing and harrowing. Soon after this a gentle all-day rain came. As soon as the surface was sufficiently dry, the entire field was harrowed. The field was seeded September 20, with 25 pounds of wheat. The yield in 1905 was about 50 bushels per acre for the first plowing, while the second plowing yielded only 20 bushels per acre. The reason for this very marked contrast lay simply in the fact that the first plowing was done when the soil was in perfect condition, while the second plowing was done when the soil moisture had been sapped to such a low degree by the growing weeds that it broke up lumpy and could not be forced into a fine, compact condition.

There are many lessons to be drawn from these results. The same amount of plant-food existed in the entire field, but in one part there were two and a half times as much available. Fig. 548, referring to the germination of wheat, illustrates the two conditions very clearly. On the left is the ideal condition, that can be attained easily at a nominal expense. By the use of the sub-surface packer when the soil is in proper condition, as previously explained, there is developed a fine, even, firm condition to a depth of seven inches; then with the Acme harrow a fine loose mulch about two inches deep is secured; with the closed-heel shoe drill the V-shaped opening into which the grain drops is made about one inch deep in the firm soil beneath the mulch. When the seed reaches the bottom of the opening it is surrounded, except over the top, with fine, firm, moist soil. The fine dirt that very naturally fills this opening as the shoe moves along, leaves the wheat in the ideal condition. The numerous small moist particles of soil that come in contact with the seed convey the moisture quickly and in ample quantities. This, together with the air from above, brings about the very remarkable germination and development shown at the extreme left (Fig. 548), in the short space of five days. This result has been accomplished over and over again.

In Fig. 548, the single grain at the right in the left-hand section is simply to show the surrounding conditions as it is deposited, compared with those in the loose soil at the right. The relative conditions should be thoughtfully observed. In one case, moisture is ample because of the fine firm soil, and a continuous supply afforded by the more rapid movement of moisture through increased capillary attraction brought about by the finer pores of the firmer soil. On the other or coarser side, the water-holding capacity is very much less, and because of the coarser and more open conditions water rises very slowly. The development of roots is also very much less. It is in this kind of soil that grain suffers most during hot, dry periods.

Some advantages of summer culture.

Among the marked advantages of the summer culture method may be mentioned the following:

(1) The storage of rainfall of practically one entire season. By repeated experiments it has been shown that, with the average loam soils and clay subsoils of the western prairies, there is little or no moisture lost by percolation, as it practically all comes back by capillary attraction as needed by the plant, or is allowed to evaporate.

(2) By the fine, firm fitting of the lower part of the furrow-slice, three important conditions are established for the anticipated crop: The water-holding capacity of the part where the main feed-

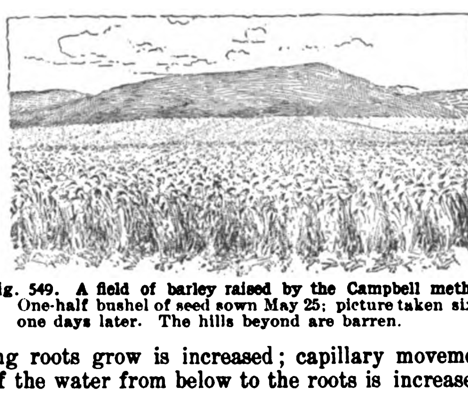


Fig. 549. A field of barley raised by the Campbell method. One-half bushel of seed sown May 25; picture taken sixty-one days later. The hills beyond are barren.

ing roots grow is increased; capillary movement of the water from below to the roots is increased; and the development of the root system of the plants is greatly augmented. These three conditions together often result in the carrying of a crop through a long, hot, dry period without injury, when under the more common conditions crops would be seriously damaged or entirely ruined.

(3) By the fining and firming of the lower side of the furrow-slice, and the constant maintaining of the loose mulch on the surface, the most ideal conditions for bacterial action and the production of humus and nitrates are established. The requirements for bacterial action, nitrification and growth are a proper supply of moisture, air, heat and light. Heat and light are naturally supplied. The physical condition of the soil largely regulates the supply of air and water. The forming of a crust on the surface shuts out the air as does the crust under the mulch. In proportion to the density of the crust and the shutting out of the air is nitrification checked. When a crust is allowed to form on the surface where there are growing plants, it will soon be noticed that the leaves begin to turn lighter colored and that growth is checked.

Some specific results of summer culture.

The results secured during the years in which summer culture has been practiced demonstrate very clearly the value of the method. On a farm in Kansas given this treatment, when the excessively hot summer of 1901 caused many fields of wheat to be entire failures, there were harvested 41½ bushels of wheat. The field was summer-tilled again in 1902, since which time three successive crops have been harvested, aggregating 118½ bushels per acre. A fourth crop this year (1906) will not lessen the average. The field was double-disked each year immediately after the crop was cut, and the soil was not permitted to dry or a crust to form.

In 1904, a summer-tilled field in Hitchcock county, Nebraska, where 90 per cent of the winter wheat was a failure, yielded 41 bushels of 60-pound wheat per acre. At Holdrege, Nebraska, the second crop since summer tilling has been harvested, yielding 50 bushels per acre, while a field on an adjoining farm, suffering from drought, produced 8 bushels.

These facts show that by taking care not to allow the soil to get dry after one summer tilling, four or more successive large yields may be secured. Many farmers have reduced the succeeding year's crop by allowing the soil to dry in the fall. A great increase in grain production would result if the farmers would not permit this drying; and if they would plow only when the soil is moist and not when it is either wet or dry.

FARM TERRACING IN THE SOUTH

By *Hugh N. Starnes*

Throughout the red-clay cotton-belt of the South, prevention of soil erosion is an absolute necessity. It there assumes an importance accorded it in no other section of the globe; for the soil is freestone, formed by the disintegration of granitic rock, and the surface is everywhere hilly and irregular and frequently badly broken. As "clean culture" is an essential of the cotton crop, the soil is soon depleted of its original store of humus—never very plentiful—and, as there is no lime to flocculate the soil particles, the resulting denudation, although the annual rainfall does not exceed 48 inches, would quickly become ruinous were not some system of retention and renovation employed. Retention is afforded by the so-called "terrace," and renovation by the "triennial crop rotation system." [This system is discussed in Volume II of this work.] Terracing is now almost universally followed, while crop rotation is being gradually adopted. Wherever both have operated together for any length of time the improvement is obvious and the increase in land values emphatic.

The terrace is at first really not a terrace, but a dike or "list" made by lapping two furrows with a heavy plow. Eventually, however, the area so protected becomes a series of actual terraces, as the soil is turned down hill at every breaking by means of a reversible or "hill-side" plow. Some eight or ten years are needed to effect this.

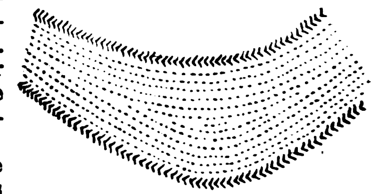


Fig. 550. Level terrace. Short rows in center of area.

There are two methods employed in terracing:

1. *The level terrace* (Fig. 550).—This is the system most frequently used, though it is inferior to the second form, or the "graded" terrace. In its construction the highest point of land in the field is first located. With a theodolite, or some cheaper form of "farmer's level," a second point is located three feet lower than the bench mark (the highest point chosen) and projected at an exact level across the sweep of the field. Temporarily pegged out at first, this line is marked by a "scooter" plow furrow; other lines are similarly located until the bottom of the slope is reached, each furrow being three feet lower than the one above. A heavy list is then thrown on the "scooter" furrows and the work is done. Each year the incipient terrace grows in height under the breakings by the reversible plow, until the hillside eventually becomes a series of steps or benches. Should there be uncleared land above the starting point it is necessary to intercept the storm-water by a hillside ditch, carrying it out of the field. Small washes or gulleys over which the terraces pass are filled at such points, and the terraces strengthened to withstand the accumulation of water. It is frequently the practice to seed down the terrace slopes with tall meadow oat-grass, vetch or fescue-grass; but in most cases they are allowed to grow up in broom-sedge (*Andropogon scoparius*).

The rows, under this system, are also run on a level and are made to parallel alternately the upper and lower terraces. This of course throws the "short rows" in the center of the area, for the slope is seldom uniform or the terraces parallel. This carries out the principle underlying the "level" terrace—that the function of both terraces and rows is to intercept and hold water, not to conduct it. This is theoretically correct, but in practice not always possible. At times the over-accumulation causes disastrous breaks and washes.

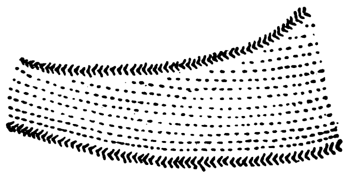


Fig. 551. Graded terrace. Short rows begin at upper terrace.

When the hillside is very steep and the area between terraces therefore rather narrow, a drop of 3½ or even 4 feet instead of the standard 3 feet is frequently employed.

2. *The graded terrace* (Fig. 551).—This is not so largely in evidence as the "level" terrace, but it is safer and more effective where there is excessive rainfall. Each terrace begins on that side of the area that has the steepest slope and is made with a uniform grade of 4 to 6 inches per 100 feet; the rows are all made to parallel the lower terrace, thus throwing the short rows, if any, not in the center of the area, but next the upper terrace, at its lower end. Each row thus carries its own water to the end of the field instead of arresting it and damming it at all points; and the grade is so slight that it travels slowly, gains little impetus and discharges but a small quantity under a normal rainfall, practically as much being absorbed as with the "level" terrace, while the danger of a disastrous break is greatly reduced.

When terraced areas are planted in fruit, as peaches or grapes, in order to obviate short rows, it is customary to "flare" the rows, contracting their distance apart on the steep side of the hill and expanding it at the other end, so that the rows will be continuous (Fig. 552). Thus the width of peach rows may be 15 feet at the beginning and 19 feet at the end, or an average of 17 feet. In commercial planting the distance apart of the trees in the row may be roughly increased or diminished to make compensation for the "flare," and so allot each tree the same number of square feet for feeding purposes. As the alignment is in one direction only and generally in a curve, this does not interfere with the symmetry of the orchard.

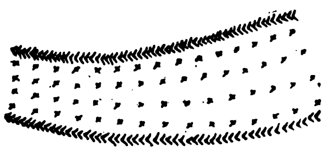


Fig. 552. Flared rows of terraced orchard.

CHAPTER XII

THE TREATMENT OF THE SOIL WITH REFERENCE TO MOISTURE

REGULATING THE MOISTURE CONTENT of the soil is rapidly coming to be as exact a process as regulating the plant-food content. The three great means of regulating the moisture supply are tillage, underdrainage, irrigation. Tillage has been discussed in the preceding chapter.

Underdrainage is accepted in theory as a cardinal agricultural practice for all humid regions. Yet the thorough practice of underdraining is still the mark of a man who is in advance of the general accomplishment of his day. Underdraining is not a recent practice; but the use of tiles, regularly prepared for the purpose, is of very modern application. The beginnings of tile underdraining in this country appear to have been made by John Johnston, of Geneva, New York, about seventy years ago. A running sketch of Johnston's work may be useful, not only for its intrinsic value but also as an illustration of the great contrast between the methods of accomplishing new things in the old days and at present.

Beginnings of tile drainage in the United States.

It was in 1835 that John Johnston, a sturdy and enterprising Scotchman, imported from Scotland a few drain-tiles to lay in the "cold, wet, clayey soil" of his western New York farm. Fourteen years before, in 1821, Mr. Johnston, then a man thirty years old, had come from Scotland and had bought a farm near the northern end of Seneca Lake, near Geneva, and which was even then said to be worn and poor. He had ridden on the top of a vehicle in going from his home to the seaport, and at night he had spied a fire burning in the fields. He asked the driver the reason for the fire. "Oh, the fools are burning crockery to put in the ground," he replied. Johnston was alert and made further inquiries; and his interest bore good fruit in after years. But young Johnston seems to have had earlier lessons in draining than this, although apparently not with tiles. "Verily all the airth needs draining," his grandfather had told him, and Johnston once said, years after, to a friend, "Whatever I know of farming I learned from my grandfather." Later, when he saw that his land was cold and backward, he considered the grandfather's opinion and the crockery that was burning in the Scotch fields. He resolved to try tile-drains. Of course the neighbors would laugh at him, and wiseacres would predict his doom. But they had done this before, and Johnston did not care. He ordered tiles from Scotland. They reached New York harbor on the night of the memorable fire of 1835, and Johnston was much concerned, for fear that the ship had burned and the tiles were lost. But they reached him safely — a small pile of the heavy, open-bottomed horse-shoe tile which is exactly depicted in the initial at the opening of this article. A curious lot of on-lookers came to see them. Here was something new under the sun, and everybody was incredulous. How could the water get into them? How could it overcome the pressure of air at the outlet? They would freeze. They would crush. They might poison the land. They would draw the water all to one place, and make that place wet. They would dry out the land in the summer. One can imagine the objections and the wise comments. But John Johnston buried his crockery in the ground out of sight, nevertheless.

Fig. 553. John Johnston.

The experiment was a success, and he sent to Scotland for patterns and had tiles made by hand. In 1848, a neighbor, John Delafield, imported a Scraggs' tile machine from England, and from that time on tile-draining progressed rapidly. It is interesting to know that in 1853 Mr. Delafield was elected president of the "New York State Agricultural College" that was to be established in that region; but Mr. Delafield's death brought the college project to an end. In 1851 Johnston had laid sixteen miles of tile on his own farm, and in 1856 there were over fifty-one miles. He used the horse-shoe tiles to the last. He did not favor deep ditches. Ditches two to two and a half feet deep, and laid as close as twenty feet apart, were his ideal. Theron G. Yeomans, at Walworth, in an adjoining county, was soon attracted by Johnston's success, and these three men—Johnston, Delafield and Yeomans—assiduously spread the gospel of tile-drains. The old Yeomans dwarf pear orchard, planted in 1852 and still vigorous, is on thoroughly tiled land. Robert Swan, an intelligent and wealthy man, was also attracted by this new farming; for a time he lived with Johnston, and he married one of his daughters. He bought the adjoining farm, Rose Hill, which had long been known for its beauty and fertility, and there constructed the first consecutive and ideal system of farm drainage in this country. Johns-

Fig. 554. The John Johnston homestead.

ton had done his draining by piecemeal, feeling his way carefully and often waiting for the increased returns from crops on the newly-drained lands before proceeding farther. But Swan planned and carried to completion an extensive and homogeneous system. Rose Hill became renowned for its splendid achievements and the beauty of its fields and buildings; and it yet remains one of the finest examples of the palatial farm homes of the last generation. The impulse of all this experiment was after a while felt throughout the county. A neighboring farmer, writing in 1866, declared that he was going to build a barn "after my land is drained and I have had two or three of John Johnston's wheat crops." The Johnston farm and Rose Hill, both still productive and beautiful, are together important historic spots in American agriculture.

The clay farm began rapidly to improve with the laying of the tiles. In fact, the draining is said to have paid for itself as it progressed. The wheat, which was always Johnston's leading crop, jumped at once from the indifferent yields of fifteen and twenty bushels to over thirty and often over forty bushels. But this gain was not all due to tile-draining. John Johnston was a good farmer in every way. He believed in excellent preparation and liberal manuring. Sheep were great favorites with him, often quite as much for their manure as for their flesh and wool, and he found most money in feeding them when grain was high, because competition was less.

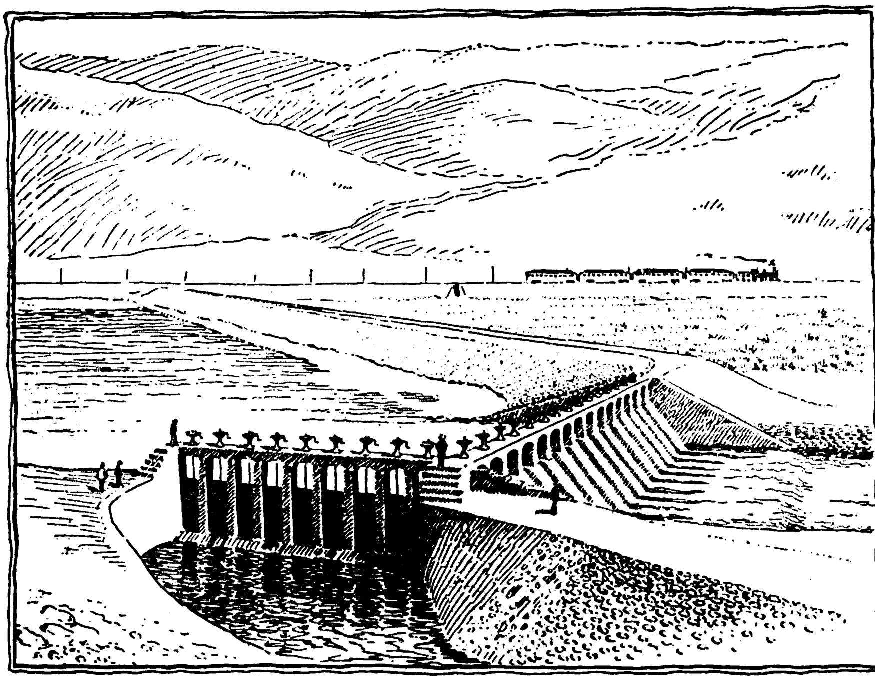


Fig. 555. Large irrigation constructions of the West. Head-gate and diverting dam of Truckee River Irrigating Canal, Nevada.

The old homestead, which was built in 1822, still stands on a sunny corner, screened by locusts (Fig. 554). There are many curious nooks and crannies inside, and in one of the larger rooms is a Franklin fireplace, that was early brought from Virginia by Mr. Rose and sold to John Johnston in 1834. The barns stand across the highway, against the roadside.

The estate is now owned by Charles Rose Mellen, a connection of the early occupants of Rose Hill, and no man could be prouder of his possessions. He lives in the old homestead, and crops the fields in the most approved methods. The drains are all in perfect condition, and the fields are still as productive as ever.

John Johnston was tall and spare, with intellectual and striking features. He gave the closest personal attention to all the details of his farming from 1821 to 1877, when the infirmities of age made it necessary for him to rent the farm. He was born April 11, 1791; he died in Geneva, November 24, 1880.

The late Joseph Harris was always a warm friend and ardent admirer of John Johnston, and a few sketches from his pen will portray the character of this sturdy pioneer: "John Johnston talked of giving up farming [1868]. He was over eighty years old and had no son; help scarce and not trusty. 'Had I not better sell?' he asked. I wrote him 'No.' Fancy John Johnston in a city! No underdrains, no growing of crops of grass and clover, no wheat, no corn, no barley, no sheep! The last time I was there, when he went into the field his favorite cows came to be patted, and a splendid heifer calf put her nose into his arms. Shall he leave them? Those who say so know nothing of the pleasures of farming. He now writes me: 'The farm is not to be sold. I have let forty acres for five years for nursery purposes, at a yearly rent of $1,000, payable semi-annually. This is a great deal better for me than selling. It would have been a great trial to have left my farm. I still have over fifty acres of cleared land, and you may be sure I will do my best with it. I have sold this year's crop of wheat for over $1,500. I have 900 bushels of ears of corn from a trifle over eleven acres, and at least seventy tons of hay. I have bought 300 wether sheep and ten tons of oil-cake. Won't I make manure for my small farm! . . . Twenty-five dollars per acre rent (5 per cent on $500 per acre) is not a bad price for a farm which was once said to be "the poorest land in creation." So much for thorough underdraining, good tillage, liberal feeding and high manuring!'"

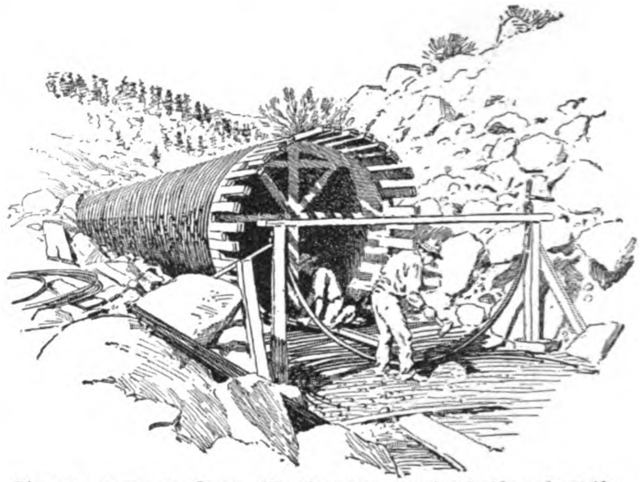


Fig. 556. A monster flume. Nine-foot pipe, showing inside and outside forms and method of breaking joints. Floriston, California.

"I have visited John Johnston a great many times, and wish every young farmer in the country could enjoy the same privilege. He is so delightfully enthusiastic, believes so thoroughly in good farming, and has been so eminently successful, that a day spent in his company cannot fail to encourage any farmer to renewed efforts in improving his soil."

The significance of irrigation.

Irrigation is much more than a system of farm practice. In the arid West, at least, it underlies the very existence of a complex civilization, and is, therefore, the broadest kind of public question. In fact, irrigation is growing into a really national problem. It is a national question because it touches the very fundamental conditions underlying the development of a third of our domain, since it touches large administrative affairs associated with public land and forests and water-ways, and since it is bound to color the representation in Congress and consequently the attitude of that body to many correlated questions. It is also to become a national question in a very different way: the arid West is to inspire the humid East to a more accelerated agriculture. We usually think that irrigation is an affair only of arid regions; but as exacter methods of crop-control are demanded, every region in which serious droughts recur must supplement rainfall by means of artificial water-supply,—in fact, we shall come to apply water for the purpose of better utilizing the soil quite independently of mere droughts. The large and free agricultural ideas of the middle West are reacting strongly on the East and South and are challenging the conceptions of what constitutes efficient farm organization; another reaction is bound to come from the irrigation practice of the arid West, and this will make irrigation a national question in an agricultural and economic way as well as in a governmental and administrative way.

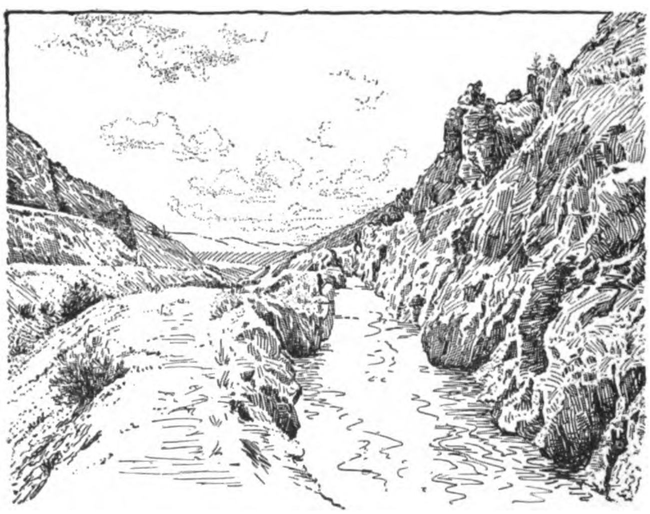


Fig. 557. An irrigating ditch (at the right) carried alongside a rugged valley.

In irrigated regions, there is a conviction that the best agriculture, and therefore the best country life, is to develop in arid America. This is a result of the belief that a completer and exacter control of the land can be secured by means of irrigation than by relying on the uncertainties of rainfall. Many persons think that the only really predictable and dependable agriculture must rest on irrigation. It is true that a dependable irrigation reduces one of the great elements of uncertainty and risk; but not all irrigation is dependable in the amount and quality of water, and the extent of land that can be brought into cultivation solely on irrigation-supply of water is relatively small. It is a fair question whether the highest skill may not be required in those regions in which the elements of risk are most numerous, for the greater the number of the problems the more alert and resourceful must the farmer be. At all events, the humid regions must be cultivated; but in these very regions, one of the largest risks will be removed by supplementary irrigation. The question, then, in these humid regions will be not only the adding of water at certain times of the year but the removing of superfluous water at other times: irrigation and drainage will be coördinate practices.

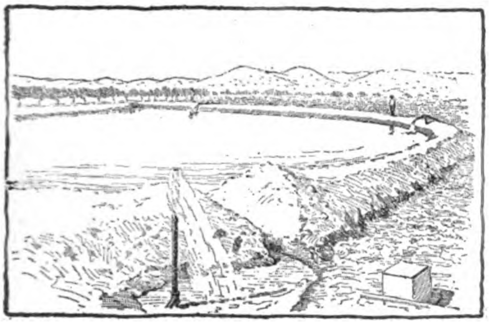


Fig. 558. Artesian irrigation. A reservoir near St. Davids, Arizona, for collecting the flow of three small artesian wells, securing a large head of water for irrigation.

The days of pioneering in the old way are now practically done. The irrigation systems worked out by the Mormons and others have shown the way for the development of most of the farther West. This experience has now culminated in the national Reclamation Act, setting aside sales of public lands for the constructing of irrigation works. This act was signed by President Roosevelt June 17, 1902. This signalizes a system of national undertakings comparable, in many ways, with the river and harbor improvements. It has also put the moral support of the nation behind the development of the West; and it is easy for the political philosopher to follow out what some of the consequences are likely to be. It is not to be expected that the national reclamation service is to reclaim to cultivation all of the arid West, or even any considerable part of it; but in setting its machinery at work, it has also stimulated the discussion of all the questions that center about irrigation, and, therefore, around the development of the western country, and is helping to take this development out of haphazard and pioneer and propagandic methods into ways of permanent orderly procedure. The irrigation movement has now reached its educational and scientific phase.

A definite line of policy in respect to settlement of reclaimed lands was voiced by President Roosevelt in his message to the Thirteenth National Irrigation Congress, at Portland, in 1905, and also by President Pardee, Governor of California, in his presidential address, and re-echoed at many times and in many ways during the convention. In President Roosevelt's language, it is this: "No man should be permitted to take or occupy more of the public land than he can put to beneficial use. And so far as it can be done with safety to the great interests of the nation, every man who will put public land to its highest use by making his permanent home upon it should be allowed to take enough of it to support that home, of course under the necessary restrictions." Governor Pardee stated the subject thus: "The economic welfare of the whole country is involved, for the ultimate object to be attained is the upbuilding of national prosperity upon the most enduring of all foundations: the largest possible increase in the number of small property owners and the multiplication of homes." The tone of the convention was wholly removed from land-grabbing schemes or mere "promoting" enterprises: the West must grow and improve, and the irrigation service is the result of a perfectly normal natural development. No such tremendous areas of land will be suddenly thrown on the market, to the upset of eastern agriculture, as many per-

Fig. 559. Irrigation of a garden. The water from the Gila River is carried through furrows. Prima, Arizona.

sons have feared. The areas that can be reclaimed are, after all, relatively small; and the expansion may be expected to be nearly all absorbed by the natural growth of the West itself.

A most impressive note in the irrigation conventions and congresses is the forward look and the spiritual significance of the gatherings. This note signifies how fundamental are the questions involved in the discussions. One could not hear the great Mormon chorus of more than two hundred voices rendering the "Irrigation Ode" at Portland, with mighty volume and swing, without feeling that in arid America a new kind of poetry and literature is to be born and a new direction is to be given to some of the currents of civilization. One feels that this western civilization is fastened directly to the land, and that the effort is always to stand on the soil; and it therefore has an indigenousness and nativeness that one vainly longs for in many other countries. It is inspiring to hear an ode on the actual affairs whereby men subsist.

Two stanzas from the Irrigation Ode, by Mrs. Gilbert McClurg, will show its spirit. The first stanza is "The Desert":

(*Recitative*) Oh! desert land!
The land of the smiting sun-glare, deep-blue of the star-pierced night,
Of rock-piled heights and chasms, awe-fraught to the dizzying sight,
Where the shadow ever chases the light of the blinding day
With purple and pink and crimson, opalescent and far away!
The candlesticks of the cactus flame-torches here up-hold;
Sunflower disks and feath'ry mustard spread fields of the cloth of gold.
The polished cups of amole are girded with spears of thorn—
When the desert wind arises,—and they fade as they are born!
The rainbow-colored spaces, wan and withered in a breath;—
Bones of man and beast lie together, under mirage-mock of death!

(*Chorus*)
Life of sky and sand awaking to prey when all is done;
Land of the desolate people, born of sirocco and sun!
(*Recitative*) Oh! desert land!

A subsequent stanza is "The Irrigated Region":

(*Recitative*) Oh! glorious land!
The land of homes for the homeless; of shepherded flocks and herds;
The land where the green-walled thickets are choral with songs of birds;
Where, over the ancient furrows, silver streamlets are re-drawn;
Where slopes, once arid, lie teeming with wealth of the vine and corn;
The land of sunny spaces, the land of the leafy glades;
Of the faith that sees in the desert the promise of verdant blades,
Where fruits, purple, crimson and golden, roll forth from Plenty's horn,
Where souls of noble fealty, of diviner mood are born;—
Where, on glimmering heights of future, gleam fair regenerate years,
Read in crystal chrism of water, the transparent globe of seers!

(*Chorus*)
In the garden grows the Tree of Life where Eden's rivers run,
Land of the world-dowered people, nurtured by water and sun!
(*Recitative*) Oh! glorious land!

THE MOISTURE OF THE SOIL

By *J. A. Bonsteel*

The importance of a proper amount of soil moisture in crop production cannot be overestimated. The higher plant forms, which constitute the forage, grain and food crops of the country, are able to secure their nourishment from the soil only through the medium of the soil moisture and of the material which is dissolved in it. The same plants, though abundantly supplied with dissolved plant-food, cannot live unless relatively large amounts of soil water are taken from the ground, carried through the plant and evaporated at the surface of the leaves. The failure to perform these two functions gives rise to the respective results of plant starvation and drought. Soil moisture also performs other functions, such as the equalization of soil temperatures, the distribution of soluble fertilizing materials, the maintenance of chemical and physical activities, and even the function of controlling in a measure the bacterial life of the soil.

The dissipation of rain-water.

The common source of soil moisture is rain-water. When the moisture of the air condenses into drops and falls to the surface of the ground its fall seems to be stopped, but is in reality only retarded. A part of the rain-water is speedily evaporated back into the air. In summer, on heated barren sands, this amount is undoubtedly large. Under other circumstances it is usually small. Another part of the rainfall gathers into drops; these coalesce into rills; they in turn form little brooks, and the surface drainage of a field or a county results. The quantity of rain-water which meets this end varies with the compactness of the surface soil, the amount and character of the vegetation, the slope and surface configuration of the land and rate of evaporation, as has been pointed out. Thus, a sudden dashing shower falling on a bare, compact, clay surface gives rise to a large quantity of surface water which finds its way into streams, rapidly if the slope is great, more slowly if it is small. The moisture from such a shower is chiefly disposed of by surface drainage, or "run off", and vegetation derives little benefit from it.

A third part of the rainfall passes slowly into the soil. It is a mistake to suppose that it sinks into the soil through the innumerable pore spaces which exist between the individual soil grains, or that these pore spaces are filled until the soil is saturated. On the contrary, in the case of all of the heavier clays and loams, in fact in all but the most porous sands, the rainfall penetrates the soil chiefly through cracks, joints, crevices, angleworm burrows and the tubular spaces left by the decay of plant roots. Only a gentle, long-continued "soaking" rain is capable of utilizing fully the many avenues of circulation presented by the average arable soil.

However, when the atmospheric moisture has begun its career as soil moisture by passing into the larger openings, it speedily soaks into the mass of the soil through the smaller pore spaces that are found in even the stiffest clays.

In a majority of cases even a large rainfall is rapidly absorbed within the surface six inches or one foot of ordinary cultivated soils. Some part of the water does not cease its movement at this stage. It continues to fall through the larger openings until it meets with some less pervious layer of clay or with rock. It may then flow away along the surface of such a stratum, finally escaping at a lower level in the form of springs, or it may be denied such an outlet and accumulate as ground water. When the ground water approaches near to the surface the land is called boggy or wet. When it reaches the surface, a swamp, a spring, or a lake may be formed.

The water that runs off the surface is of little use to vegetation. That which forms springs by flowing far under ground is usually of small value to growing plants. That which accumulates as swamps or marshy spots is of positive harm to all but a few species of cultivated plants.

So far as agriculture is concerned, it is the relatively small amount of moisture that remains absorbed in the partially dry surface layers of the soil on which crops depend not only for their water-supply, but also for their supply of mineral plant-food. This soil moisture usually forms rather thin films surrounding the small soil grains and occupying the small angles where they touch. This moisture is in contact on one side with the mineral and dead organic matter of the soil and on the other with the soil air which almost always occupies a large part of the open porous space in the soil. When plants are growing on a soil, their roots and root-hairs are also in contact with the soil, the soil moisture and the soil air.

The function of the soil moisture.

As a solvent.—The rôle played by soil moisture is extremely complex. No water which falls on the soil is pure. During its passage through the air as rain it has absorbed small but measurable amounts of carbonic acid gas, ammonia and oxygen, besides

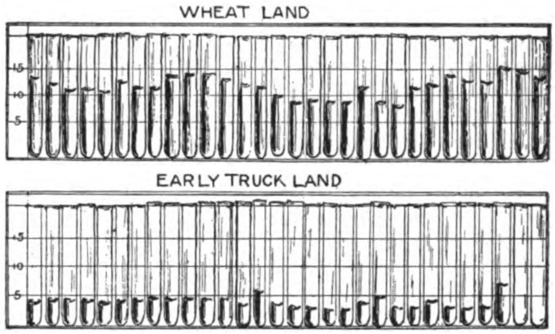


Fig. 560. Water content of typical soils. Soil moisture actually found in thirty samples of wheat soils and in twenty-eight samples of truck soils. Figures at left (5, 10, 15) indicate percentage of moisture by weight.

other impurities. When it comes in contact with vegetation and particularly with the decaying litter found on the surface of almost all soils, it takes on more carbonic acid gas and also certain other weak acids that are the product of vegetable decay. Thus armed, it sinks into the soil in the form of an active solvent of many materials.

Almost all of the minerals that compose soils may be dissolved by water that is chemically pure. There are no known minerals occurring in the soils that cannot be dissolved to some extent by the impure water that enters the soil after a rain. Even those minerals, like feldspar, which are least soluble directly, are chemically attacked by the soil water and by the impurities which it bears, so that their store of material suitable to form plant-food is slowly but surely and continuously liberated. In this way the supply of plant-food is derived from the mineral matter of the soil, and few known soils are so simple mineralogically or so difficult of solution but that plenty of water properly supplied is able to continue to unlock plant-food at a rate sufficiently rapid to nourish plants. Whether plants can grow on soil depends on a variety of other factors, some of which are totally unconnected with the soil itself.

As a carrier.—Soil moisture is required to transport plant-food into the plant as well as to prepare the food for presentation to the plant. This transportation may be accomplished in a variety of ways. The water and the plant-food dissolved in it may pass bodily into the plant-tissues to supply the place of the water evaporated from the leaves. The water after evaporation is pure, or distilled water. The impurities, whether helpful or harmful to plant-life, remain behind to be disposed of by the plant. Again, the dissolved material in the soil moisture may pass into the plant-tissues independently of any movement of water or in a contrary direction to that of water movement, just as a lump of salt placed in the bottom of a tumbler of water will dissolve and its particles pass to all parts of the water of the tumbler. This process is known as diffusion, and it plays an extremely important part in plant feeding. Whenever the amount of any dissolved matter in the soil moisture is reduced through diffusion and its use by the plant, the soil moisture gains new power to dissolve more mineral matter of the same kind to take its place, so that the soil moisture is capable of continually replacing the used material by further solution of the mineral matter of the soil. This is one of the chief functions of soil moisture and one which is just coming to be understood.

To maintain turgidity.—All growing plants require water to distend the many cells of which they are composed and thus to maintain the plant against what is called wilting. An immense amount of water is evaporated constantly from the large total surface of the leaves, and this water must be re-supplied from the soil moisture. It has been estimated that in order to produce a full crop of any one of the cereal grains at least 250 pounds of water must be supplied for every pound of dry matter produced, both stalk and grain. It would then require 200 tons of water to produce the grain alone of 30 bushels of wheat. The straw would require as much more, while the roots and stubble would also need to be provided for.

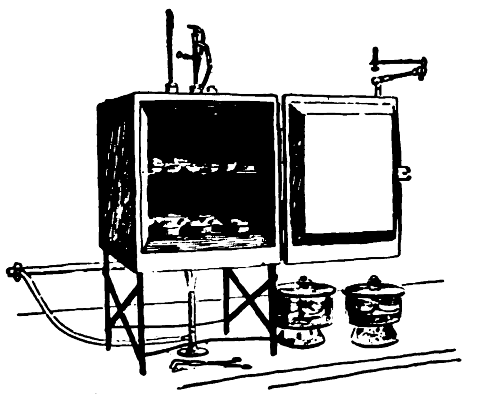


Fig. 561. Moisture determined by the method of drying samples. A comparison of the weights before and after drying gives the amount of moisture in the soil. This method may be used by the farmer to determine the moisture. A tin cup full of soil can be dried in an ordinary oven: the loss of weight constitutes the moisture lost.

Of course the amount of moisture required to prevent drought or wilting varies with the kind of crop, the character of the climate and the texture of the soil. Oats and corn require large amounts of moisture, potatoes smaller amounts. More water is normally required when the air around the plants is dry than when it is wet. No two soils have the same characteristics in regard to the rapidity with which they can supply water to plants, nor in regard to the total amount they must contain to remain above the drought limit. Moreover, the same individual plant requires water supplied more rapidly at some stages of its growth than at others.

The effect on temperature.

The soil moisture exerts another very important influence through its effect on the temperature of soils. It is a fact that five times as much heat, or even more, is required to warm one cubic foot of water as is required to warm equally one cubic foot of soil. Thus a saturated, water-logged soil is always spoken of as a "cold, wet soil." Such soils are late to germinate seed, since most seeds must be warmed above 45° F. before they can sprout, and plant growth is favored by temperatures ranging from 60° to 80° F. "A hot, wet day makes corn grow," is a familiar saying in some sections of the country.

Soil saturation.

The excess of water must be removed from a saturated soil before ordinary farm crops can grow. This may be accomplished by drainage, but too frequently this is not provided and the sun is depended on to evaporate the water. It requires nearly one thousand times as much heat to evaporate one cubic foot of water as it does to raise the temperature of the same mass one degree in temperature, so that the loss of heat energy experienced in warming and drying the saturated soils of the United States in one year, represents an enormous amount of horse-power if it could be so calculated. A proper amount of soil moisture helps to preserve the soil from overheating during the burning days of the dry summer, just as free perspiration preserves a man from sunstroke; but more soils are suffering from an excess of moisture than from a lack of it in the humid regions of the United States. An excess of soil moisture is present whenever the pore-spaces of a soil are clogged with water. In this condition the soil is hermetically sealed against the entrance of air, as was the milk in certain old, deep-setting cream cans. Every part of a plant which is growing, that is, which is forming new plant-cells and enlarging its tissues, must have free access to oxygen, and the air is one source of that element. Consequently, the saturation of a soil and the resulting exclusion of fresh supplies of air must result in stunted plant-growth or in the death of the plant. Even eel-grass grows only when it is exposed above tide for a part of the day; and the cypress sends its knees above water-level even when submerged only a part of the year. Cypress trees on dry land have no knees.

The conservation or saving of moisture.

The importance of soil moisture is plainly evident. The proper methods for its maintenance and control are among the most fundamental problems in soil management and farm practice.

Plowing and cultivation are processes intended to prepare a seed-bed for germinating and growing plants. At the same time, they are the most common methods of providing for the accumulation, storage and retention of soil moisture. Rain

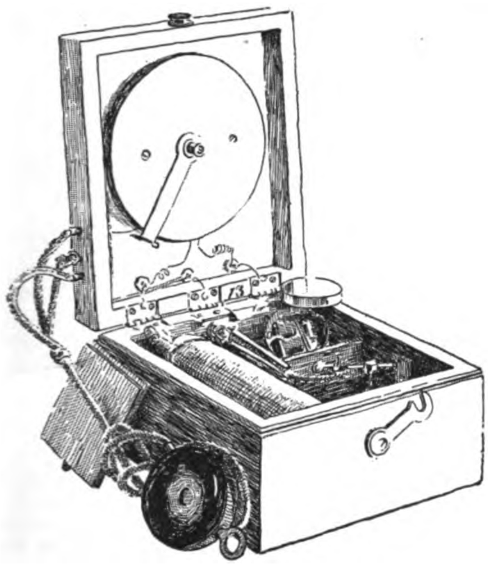


Fig. 562. Electrical apparatus for field determination of moisture in soils. Electrodes are buried in the ground at various depths in different parts of the field, and readings of the moisture conditions may be taken daily to secure a record of the moisture at different depths over an entire field. (This method is used chiefly for research work.)

falling on a puddled clay surface runs off. That is why tiles are used as roof coverings. If the puddled clay surface is carefully plowed, so that a fine, porous layer of dirt is formed, "as mellow as an ash heap," a much greater amount of moisture is absorbed and retained by the soil, its distribution is more even, and the washing away of valuable surface soil is largely prevented.

If, after the rain has fallen on a properly prepared soil, the sun comes out and burns and bakes a crust on the surface, a large amount of water may be evaporated into the air before the growing plants have had an opportunity to use it. But if the crust be broken and the surface soil stirred to a shallow depth, a mulch is formed which not only reduces the rate of evaporation but which causes it to take place well down within the soil rather than at the surface, and it has been pointed out that when the evaporation takes place there the dissolved plant-food is left in the soil in the proper place.

Proper cultivation also aids the plant materially in securing its supply of moisture by allowing its roots greater freedom. The subsoil below plowing depth is usually much more compact and much less porous than the fined and mellowed surface soil. As a result, plant-roots develop and spread to the best advantage down to the normal depth of plowing. Below that, "hardpan" is frequently struck. Proper plowing to a good depth not only increases the total reservoir space for storing soil moisture, but it also allows the roots to spread widely and freely to all points where moisture and food and air, the three essentials of plant-life, may be secured.

The removal of excess moisture.

Excess moisture can be removed only by drainage. In many cases it is necessary to dispose of temporary surface excesses of water only. For this purpose, shallow open ditches of broad U-shaped contour may best be employed. Teams and tools can be driven across them. Crops may grow in them while they are not performing their duties as drains. Frost and flood do not cave in their sides as is the case with steep-sided ditches. [This subject is discussed in Professor King's article, following.]

Summary.

In conclusion, the dominant facts connected with the problem of soil moisture may be summarized briefly:

(1) Soil moisture is an essential part or factor of the soil, since it prepares and distributes the food-supply of plants.

(2) Soil moisture largely dominates the temperature of soils, and hence influences the vitality of seeds and plants.

(3) Soil moisture admits air to the soil or excludes it, and all growing parts of a plant must have air with the oxygen it contains.

(4) Moisture in slow motion in the soil and not saturating it is uniformly beneficial to plant-life even in large amounts.

(5) Moisture stagnant in soils, or saturating them, though in motion, is uniformly harmful to all plants except especially adapted swamp species.

(6) The problem of securing, distributing, conserving and supplying soil moisture is a fundamental problem in agriculture, and many failures in farm management may be traced directly to a failure on the part of the farmer to understand or to solve this problem.

(7) The control of the kind and the amount of crops raised on the ordinary soil is so closely related to the control of soil moisture that this one factor in crop-production is the dominant factor in all ordinary agriculture. This is well known in irrigated areas.

Literature.

The subject of soil moisture is considered to some extent in most general works on soils, and the literature is varied and scattered. Specific treatment of the subject will be found in the following: Various papers of United States Geological Survey, Hydrographic Division; How Crops Grow, by S. W. Johnson; The Soil, by F. H. King; Physical Properties of Soils, by R. Warington; Mechanics of Soil Moisture, by L. J. Briggs, Bulletin No. 10, Bureau of Soils, United States Department of Agriculture; Investigations in Soil Fertility, Whitney & Cameron, Bulletin No. 23, Bureau of Soils; Mineral Constituents of the Soil Solution, Bulletin No. 30, Bureau of Soils.

THE NECESSITY AND PRACTICE OF DRAINAGE

By *F. H. King*

Both farm drainage and irrigation are looked on as agricultural practices required only in special cases; but a broader and more helpful conception is that all fertile fields must be periodically irrigated and thoroughly drained. It is true, over much the larger part of the earth's surface, that water required for the growth of crops is supplied by natural rainfall, and whenever this is timely and falls in sufficient quantity it provides ideal irrigation. It is likewise fortunately true that most agricultural lands have acquired such features, through elevation and erosion, that the excess of rainfall is opportunely removed by surface flow or by seepage, which is nature's method of land-drainage. The fundamental fact is that all lands which are agriculturally productive must be abundantly supplied with water and the surplus removed, either by natural or artificial means.

Necessities for drainage and advantages of it.

In the slow processes of weathering, which are in continuous operation in all soils, readily soluble salts are formed, some of which are plant-food materials and others are not. Soil moisture when charged above a certain amount, even if the materials are such as are directly utilized by crops, becomes destructive to plant-life, and hence sufficient drainage to remove the excess of soluble substances, whether beneficial or poisonous, is imperative for all fertile fields. In arid regions, where evaporation exceeds the rainfall, and little underdrainage occurs, the soluble salts formed by rock decay accumulate, often rendering the soil sterile because of their excess; and hence it is that even in arid regions, where irrigation is practiced, unless water enough is applied so that some drainage occurs, sooner or later the lands become unproductive through lack of drainage: not because of an excess of water, but because of a deficiency of it for the removal of substances continually forming in the soil. This would be true even if the soils were irrigated with the purest rain-water. It is only because, in the majority of cases, most lands are sufficiently underdrained by natural means so that the soluble substances do not accumulate to an injurious extent that this fundamental necessity of drainage is not generally recognized.

In all humid climates when the rainfall is sufficient for remunerative crops, enough water falls to more than completely fill the pore space of the surface five feet of soil, and, were underdrainage not provided, all lands, even the most rolling, would be swampy. Surface drainage would occur as now, and evaporation, during intervals between rains, would dry the ground, through capillary action, to a small depth; but only swamp types of vegetation could thrive. All lands, to be agriculturally productive, must be underdrained, surface drainage alone never being sufficient. Ample underdrainage is imperative, because without it, below the level at which capillarity dries the soil during intervals of no rain, the water would become stagnant through lack of sufficient oxygen to meet the needs of the roots of plants and through the accumulation of poisonous substances in it. Without underdrainage successive rains would only fill the spaces of the soil emptied by capillary drying, and hence there would be but a very shallow layer of soil available to the roots of ordinary plants.

Under most field conditions the ground water is continually draining away through subterranean passages, so that with successive rains new supplies of water, highly charged with oxygen, pass into the root zone, not entirely removing the groundwater retained within the soil granules, but sufficiently diluting it when overspreading the surfaces of the granules with fresh water so as to keep it sweet. Further than this, whenever the underdrainage is deep the ground-water surface is maintained so far below the root zone that the soil moisture retained by capillarity within it is being continually recharged with oxygen through an interchange of air. Ample underdrainage is therefore an indispensable condition for agriculturally productive fields, because without it a proper aëration of the soil in humid climates would be impossible.

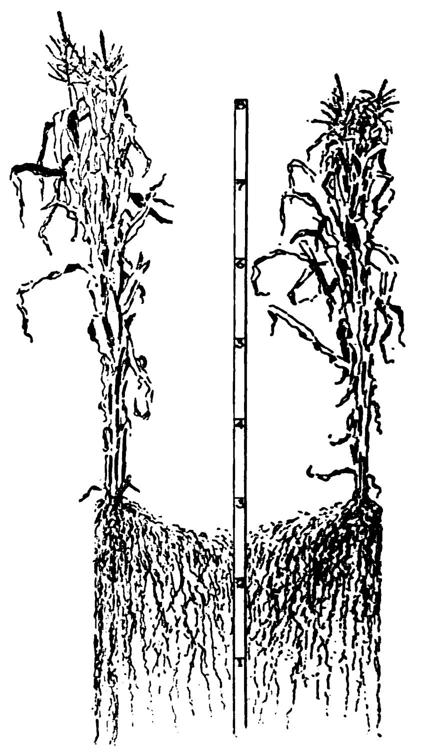


Fig. 563. Showing amount and distribution of corn roots under natural field conditions.

Through the aëration which underdrainage secures for the soil we have a deeper penetration of the subsoil by the roots of plants, inducing earthworms and ants to follow, forming their more or less vertical galleries, which permit a much freer interchange of air and increase of the effective depth of soil, an essential condition for all highly productive fields. With the roots of crops working deeper in the subsoil, the clays dry out in the intervals between rains, causing great numbers

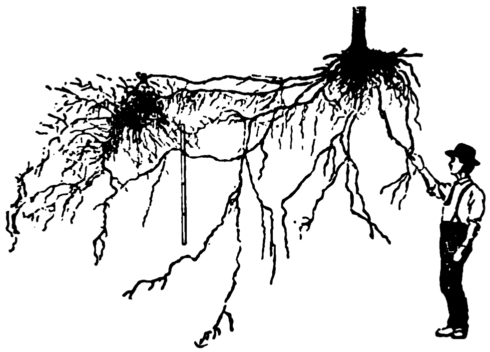


Fig. 564. Penetration of apple root in Wisconsin seven years planted. Depth nine feet.

of shrinkage checks to form, dividing the clays into very small blocks with sufficiently open spaces between them to permit the roots of plants to line the crevices so formed and the free soil air to circulate where it was not possible before. When this condition of the subsoil has been reached, the decay of organic matter charges the soil moisture so highly with carbonic acid as to enable it to act strongly on the soil, dissolving lime and other materials to flocculate the minuter clay particles and thus eventually thoroughly to granulate the clay, making it agriculturally effective.

With deep underdrainage, the direct crop-feeding capacity of the field is thereby much increased, partly because through deep rooting a much larger volume of moisture becomes directly available; partly because this moisture is spread out over a much larger soil surface where, in the condition of a thin layer with one side in contact with the soil particles and the other with the air within the soil, it is being continually charged with oxygen and with plant-food materials as the drain on it is maintained by the roots of growing crops. Further than this, with the withdrawal of the excess of moisture from the soil, leaving only that which is held by capillarity, it becomes materially warmer, and under this higher temperature plant-food develops more rapidly, particularly nitrogen in available form; seeds germinate sooner and more completely, giving stronger and more vigorous plants; so that, with the additional fact that well-drained fields can be fitted and planted one to three weeks earlier in the spring, not only is the growing season lengthened, but moisture and available plant-food materials are utilized that would in part be necessarily lost with later planting.

An impression prevails that the thorough underdrainage of a field, naturally somewhat too wet in the early part of the season, causes crops to suffer later from drought because of the withdrawal of water from the soil which would otherwise remain. It must be remembered that the underdraining of such fields diminishes rather than increases their tendency to drought, for the reason that it removes only such water as would be detrimental by compelling the roots to develop only in the upper, sufficiently drained parts of the soil, so that as the plants become larger and the surface soil thoroughly filled with them, the moisture is withdrawn more rapidly than capillarity can supply it from below. The result is that the crop suffers from drought with an excess of moisture in the third and fourth feet, and sometimes even in the second foot; whereas, if the lower subsoil had been drained early in the season, the roots could have worked downward and placed themselves in good connection with the soil of the surface four feet, where the moisture could be withdrawn by them directly from the surface of the soil granules rather than be limited to one or two feet. The rainfall of the growing season is always much more efficient on a field sufficiently underdrained, for the reason that the rain enters the soil more readily, percolating much more deeply and carrying downward with it the rich accumulation of soluble plant-food materials, which are always gathered at the immediate surface during drying times, carrying them into immediate contact with the root surfaces as they are widely spread out in the soil of a well-drained field.

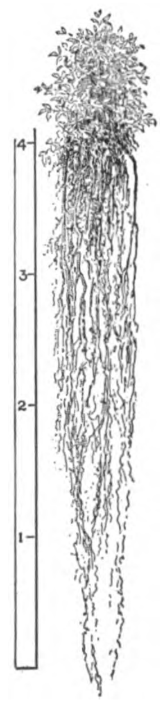


Fig. 565. Roots of alfalfa in Wisconsin 174 days from seeding.

It is not sufficiently appreciated how deeply and widely the roots of agricultural crops will spread in a soil if only it is in suitable physical condition and carries an abundance of moisture containing available plant-food. There is represented in Fig. 563 the observed distribution of corn roots in the soil beneath two rows, at the time when the corn was coming into tassel, and growing in the open field under perfectly natural conditions. In this case, it will be observed, the roots have extended downward more than three feet and laterally pass one another between the rows as well as directly downward. In Fig. 564 are shown the roots of apple and in Fig. 565 those of young alfalfa, also taken directly as they grew under field conditions.

Lands that may be improved by drainage.

A positive indication that drainage would increase the productive capacity of a soil is the presence of standing water on the surface or at three feet or less below during much of the growing season; and it is usually true that when water stands within five feet of the surface toward the close of seasons of ordinary rainfall, such lands will be benefited by underdrainage, particularly if the soils are close in texture. Very level fields composed of deep close soil, when the ground water-level is usually considerable distances below the surface, may require surface rather than underdrainage. In such cases it is a common practice to plow the fields in lands, leaving dead furrows leading down the lines of slope to surface drains that may convey away the excess of water, particularly early in the season. Often such lands may require surface drainage only during their virgin condition; and after a number of years of careful management the open texture may be so deepened as to make quite unnecessary the special measures for surface drainage, because of the increased capacity for water of the surface four feet which has resulted from its better granulation, enabling the rain to be received in larger volumes and utilized or conducted downward to a more open substratum.

In considering the desirability of underdraining a field, the general position of the water level in the subsoil may be readily ascertained with a one-and-a-half-inch auger, provided with an extension handle, permitting the soil to be bored readily to a depth of five or six feet. In making such explorations, it should be remembered that the true level of the ground water is not shown immediately by the height at which the water stands in the hole. Time is required for water to drain in sufficiently to occupy the space filled by the soil that has been removed. It should be remembered, also, that capillarily saturated soil, too completely filled with water for the best activity of either roots or soil organisms, may rise a full foot or more, according to the texture of the soil, above the level at which water stands in the non-capillary spaces of the ground. For this reason, some soils may be materially improved by underdrainage even when permanent ground water, in the latter part of the season, may be found as low as six or even ten feet below the surface.

There is an impression that deep, close-textured soils, even when the ground water is at considerable distance below the surface, may be materially improved by the laying of tile as would be done for underdraining, but with the difference that the drains should be connected with the surface for the purpose of inducing a more rapid circulation of air. In regions subject to frequent heavy rainfalls, with the surface of the fields comparatively level, and when the texture of the soil is close, particularly if the granulation is feeble, permitting the soil to run together when the surface is flooded, there is little reason to doubt that underdrains would provide a more ready exit for the confined soil air, sealed in by the accumulation of water at the surface and the breaking down of the granules, and thus let the water sink into the soil as it is not able to do without the previous escape of air. It is doubtful, however, whether laying tile drains for this purpose alone would repay the cost, except in some special cases. The same end is reached more or less effectually by other means. One of the advantages, if it may be called such, resulting from the ridge-and-furrow treatment of the surface for corn and cotton practiced so generally in the South, is the opportunity the ridges provide for the escape of soil air by drawing the rain into the furrows, leaving the ridges exposed, less completely puddled, and thus providing escape for the air as the water percolates beneath the furrows and is drawn laterally under the ridges by capillarity.

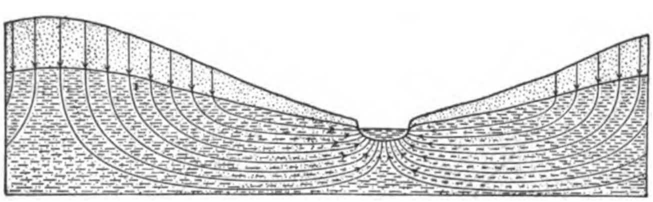


Fig. 566. Diagram of lines of flow of water in the drainage of a river valley.

In the case of rice culture, in the control of cranberry marshes, in the disposal of sewage by broad irrigation, and in the development and maintenance of water meadows, such as have been maintained for many years in Europe, where the fields are flooded periodically, there are special reasons requiring surface drainage or underdrainage or both combined.

Kinds of drains.

Natural drainage is of three types,—general seepage, surface and subterranean. The rills, draws, creeks, small streams and rivers constitute the open drains of natural drainage systems. Into these the water finds its way partly by direct surface flow; partly by general seepage laterally from their banks, as represented in Fig. 566; and partly through underground channels of various sizes, that receive their water from the soils and rock through which they lead. In artificial drainage the same types obtain, the effort being to provide the best opportunities for seepage into and discharge from them. When open ditches must be maintained to convey surface water only, it is best, whenever practicable, to make them so broad and gently sloping as to permit their being kept in grass and readily mowed with a machine. In draining peat bogs it is sometimes advisable to maintain open ditches for a time, to hasten the shrinkage of the peat, so that underdrains may be readily laid later without danger of their coming to be too near the surface with the full decay of the peat.

In many sections the surface is so nearly level that outlets for underdrains must be provided by digging extensive open ditches. When these are necessary, drainage can be carried into effect only through the coöperation of the landowners of the district. Ditches for this purpose are commonly made by land dredges, which are modified forms of the steam shovel. The ditches made with them are 6 feet to 60 feet wide on the bottom and 6 feet to 15 feet deep. Lateral ditches are placed with sufficient frequency to permit farm drainage to be completed with drain tile. Fig. 567 shows a tile-drain system discharging into the upper end of a

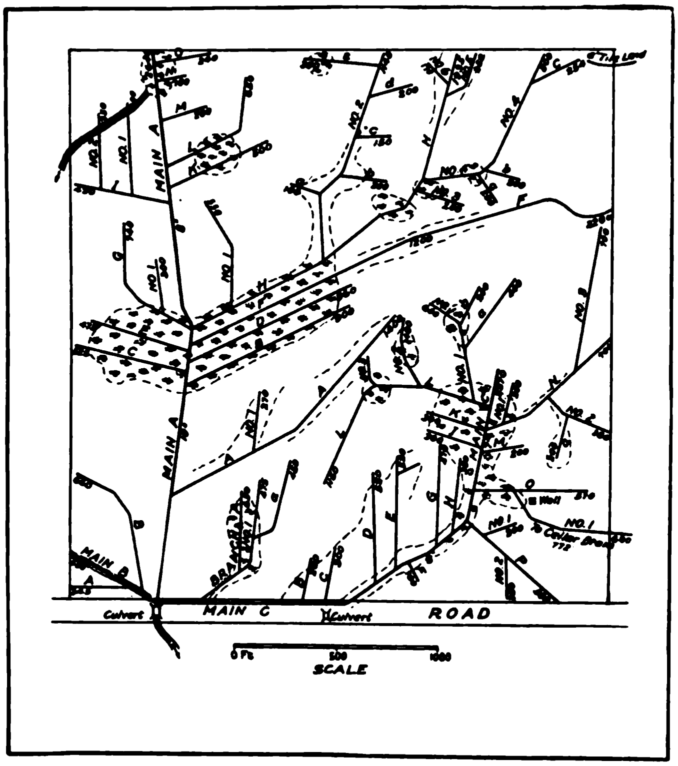


Fig. 567. Drainage scheme on a farm of 160 acres. All drainage by tile. Lines 50 feet to 200 feet apart. Surface undulating. (C. G. Elliott.)

large ditch, while in Fig. 571 a dredged ditch passes through the farm, furnishing an outlet for tile drains at various points.

In a number of states drainage laws have been formulated for directing and governing such coöperative drainage systems. The general plan is to apportion the expense of making and maintaining such open ditches to the land that they will serve, in such a way that the areas benefited bear a proportion of the cost in the ratio of the benefit received; while the detail draining of individual holdings is left for personal construction and supervision.

Closed or underdrains, whenever they can be economically constructed, are most desirable for the reason that in this form they are most effective, least in the way, require less expense in maintenance, are most permanent, leave no obstructions on the surface and waste no land. In the early history of underdraining, various types of closed drains were improvised, practical men utilizing the best that was available to them at the time for accomplishing the results they sought, just as has been the case with tillage implements. The modern cylindrical tile, made usually 1 foot in length for safe and easy handling, with diameters ranging from 2 to 12 inches or more, provides a water channel for underdraining fields that is entirely satisfactory in all essential ways. These tile should be straight, cut reasonably square at the ends and unbroken, made from a good quality of clay, very hard burned, or better carried to the extent of vitrifying. The walls need not be porous, indeed are better not so, as they are less liable to "slack" through the action of frost. There is ample opportunity for water to find its way into the drains through the joints, even when they are laid as close together as practicable. In the manufacture of the tile the cutting of them, together with the tendency to warp in handling and baking, seldom leaves the ends quite at right angles with the long axis, so that in laying, to bring the upper surfaces in contact, they are seldom close enough together at the bottom but that there is ample room for the entrance of water.

Depth, grade and distance between drains.

It is seldom necessary to lower the ground water surface in a field more than four feet, although, as indicated in the illustration of the corn roots, Fig. 563, and of the apple and alfalfa roots, Figs. 564 and 565, there is little doubt that if drains could be laid as cheaply at 5 feet as at 3 feet and suitable outlets provided, fields of greater productive capacity would be the result. Drains never lower the water below the level of their bottoms in their immediate vicinity. Between drains the ground water rises as the distance from them increases at a rate depending on the resistance the soil offers to the flow of water, on the amount of rainfall and the length of time between rains which are sufficient to produce percolation.

The surface of the ground water in a tile-drained field, as determined by careful measurements 48 hours after a rainfall of .87 inches, is represented in Fig. 568. The drains are laid 4 feet deep and 33 feet apart in a medium clay loam overlying a rather coarse sand at a depth of 3 to 4 feet. In this case, the level of the ground water, midway between the drains, was found to be 4 to 12 inches

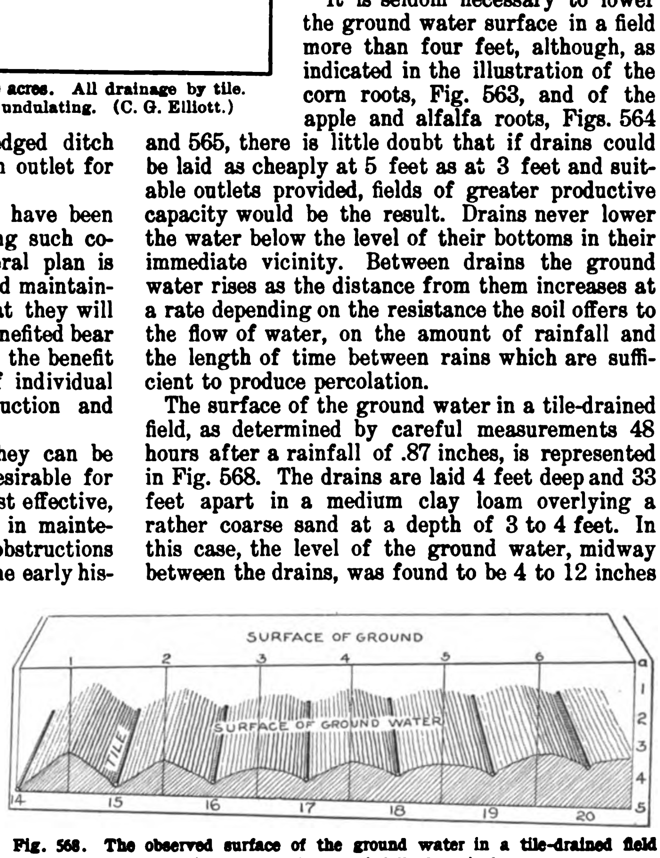


Fig. 568. The observed surface of the ground water in a tile-drained field forty-eight hours after a rainfall of .87 inches.

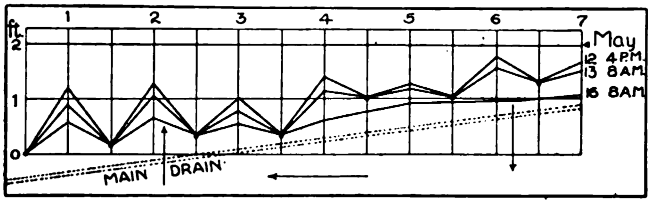


Fig. 569. Changes in the level of the ground-water surface in tile-drained field.

above the top of the drains, giving a mean gradient of 1 foot in 25 feet. At this rate of rise, drains 50 feet apart and 100 feet apart would have left the ground water midway between them 1 foot and 2 feet, respectively, higher than the level of the tops of the drains 48 hours after a rainfall of .87 inches. Other measurements were made of the levels of the water under this field after the same rain, and in Fig. 569 the heights at the drains and midway between them 32 hours, 48 hours and 120 hours after the rain are represented. In the same illustration is also indicated the level of the main drain into which the seven laterals discharged, its position being 100 feet to the west of the line of measurements. At the end of five days this main, together with the lower laterals, had drawn down the ground water 2 to 6 inches lower than the bottoms of the three upper laterals at the places where the levels were taken. The measurements, as recorded in Fig. 569, give a clear indication of the way in which underdrains influence the level of the ground water after rains. It should be further observed in this connection, that both the rate and the extent of the lowering of the water in the case observed were materially greater than they would have been had the clay not been underlaid with sand so close to the level of the drains, the water moving through the soil and to the drains in the manner and along the lines indicated by the arrows in Fig. 570. It should be said, too, that it is this type of structure that is common in lands requiring draining that makes it practicable, in such cases, to place drains so far apart. For ordinary farm crops, and ordinarily porous soils, it is common to place the laterals 50, 75, 100, 150 and even 200 feet apart, as is illustrated in Figs. 567 and 571.

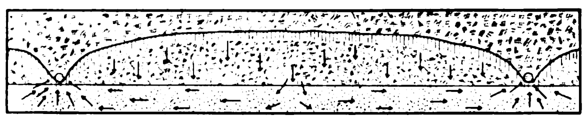


Fig. 570. Movements of water toward tile drains where heavy clay soils are underlaid with sand.

Fall or gradient of drains and size of tile.

The effort should be to lay drains so as to give them the maximum fall, making the gradient uniform, or changing, toward the outlet, to a greater rather than to a less fall in order that no clogging with silt shall occur. When a change must be made from a more to a less steep grade, it is often advisable to provide a silt-well at the point in the main where the change occurs. This is a pit 2 or 3 feet in diameter, extending as many feet below the grade line, into which the water is discharged and from which it flows after having dropped any sediment it may have brought down the steeper slope. The well should be curbed with stone or brick and provided with a cover. A fall of two inches in 100 feet gives very satisfactory results; but drainage must sometimes be done with slopes much less than this, and drains have been laid on a gradient as small as a half-inch in 100 feet. A fall of two inches per 100 feet across a 40-acre field would make the difference in level between the two sides 2.2 feet, while one of half an inch would be a difference of only 6.6 inches. In laying drains on grades as slight as these, it is evident that much care must be exercised in laying them out and in digging the ditch true to grade. A rise or fall of four inches above or below the grade line would cause part of a 4-inch drain to stand full of water, and have the effect of causing sediment to be dropped and close it up.

When large areas are to be underdrained, when the fall is small and the surface conditions complex, it will be safest to entrust the leveling and the laying out of the mains and the laterals, ready for the ditcher, to a competent and thoroughly reliable drainage engineer. Indeed, it will generally be best and more economical to let the whole job, if it is large and difficult, to a man of

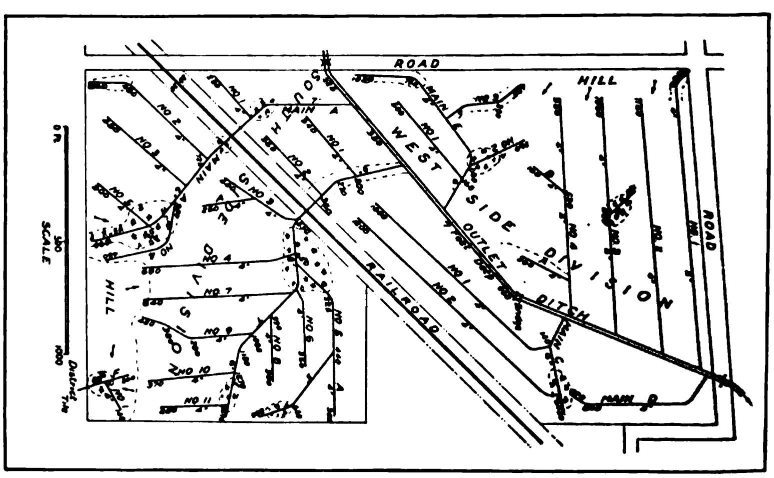


Fig. 571. Actual drainage scheme on a farm of 90 acres. Outlet ditch made with a dredge. All other drains are tile of sizes shown. Soil open; subsoil, joint clay. (C. G. Elliott.)

experience who has established a reputation for reliable work. Even in the matter of digging the ditch, and particularly in giving it its finish, as well as in placing the tile, drainage engineers

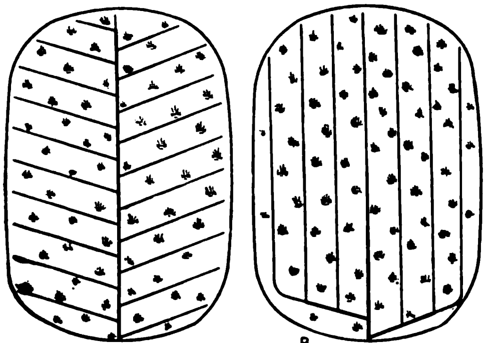


Fig. 572. Two systems of laying out drains.

themselves find it difficult to secure men who have the patience, the feeling of responsibility and the practical skill to do the work well. But while the farmer should be discouraged from attempting the drainage of large and difficult areas on his own place, it is important for him to have a clear conception of the general principles of drainage and of what constitutes good detail practice

In regard to the size of tile, it is doubtful whether it is ever desirable, even with laterals, to use sizes smaller than 3 inches, except it be in cases when the fall is large and the soil close. When single lines of drains are laid, to remove water from low places, larger sizes should be chosen than would be required in large areas systematically treated, because in such cases more surface water from the surrounding higher lands, relatively, must be cared for by such drains. The greater the fall the smaller the tile may be; and doubling the gradient increases the carrying capacity of a given size nearly one-third. When other conditions are the same, the capacity of tile increases somewhat faster than in proportion to the squares of their inside diameters.

Fig. 575. Laying tile from the top of the ditch by means of a tile-hook (tool shown at left in Fig. 578).

In determining the proper sizes of mains for the drainage of a given area, so many purely local considerations must be taken into account that specific rules that may be safely followed cannot be given. Examples of special cases will best serve the purpose. Figs. 567 and 571 represent drains laid out under the supervision of C. G. Elliott. The soil in each case is a rich black loam with yellow joint clay subsoil. The surface is nearly level, interspersed with basin-like ponds that are 12 to 24 inches lower than the surface surrounding them. The size of the mains and laterals in Fig. 571 is indicated and their distance apart may be found by applying the scale. The least grade used is 1 inch fall to 100 feet. The largest main is 7 inches in diameter and furnishes an outlet for a deep pond into which surface water gathers rapidly, requiring more ample outlet than an equal area of level field. The soil being open, nothing less than 4-inch tile is used on either of the farms represented in the two maps.

We also give in the form of a table, from Mr. Elliott, the sizes of outlet drains for specific cases

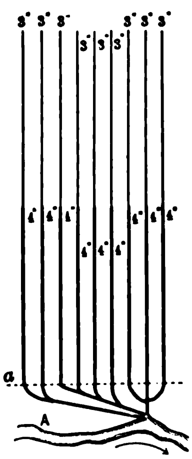


Fig. 573. One mode of laying out the lateral drains.

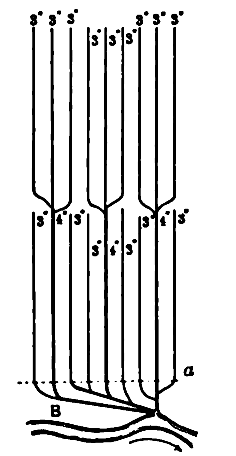


Fig. 574. A compound system of lateral drains.

in which he assumes that there is to be removed in twenty-four hours one-fourth inch of water over the areas named, when the length of the mains must be 1,000 and 2,000 feet, having the falls stated in the table:

When the fall is one inch per 100 feet, and the length is:

	1,000 feet, acres	2,000 feet, acres
A 5-inch main will drain	19.1	15.7
A 6-inch main will drain	29.9	24.8
An 8-inch main will drain . . .	61.4	50.7
A 10-inch main will drain . . .	106.7	88.5
A 12-inch main will drain . . .	167.7	139.3

When the fall is two inches per 100 feet, and the length is:

	1,000 feet, acres	2,000 feet, acres
A 5-inch tile will drain	22.1	19.4
A 6-inch tile will drain	34.8	30.5
An 8-inch tile will drain	71.2	62.6
A 10-inch tile will drain	123.9	108.9
A 12-inch tile will drain	194.6	171.6

When the fall is three inches per 100 feet, and the length is:

	1,000 feet, acres	2,000 feet, acres
A 5-inch tile will drain	25.1	22.7
A 6-inch tile will drain	39.6	35.9
An 8-inch tile will drain	80.9	73.6
A 10-inch tile will drain	140.6	128.1
A 12-inch tile will drain	221.1	201.8

Fig. 576. Roots of an elm tree in a suction pipe in a dug well three feet in diameter.

If double the amount of water were required to be removed from an acre in the same time used in the table, the areas that the different mains would be able to serve would be only half the number stated; while, if the amount of water were half that stated, the number of acres that could be served would be twice as large.

Laying out systems of drains.

In laying out systems of drains the object is to secure thoroughly efficient drainage with the least cost. To do this, it is necessary to avoid laying lines through areas already sufficiently drained; to make the outlet junctions as few as possible; to avoid the use of unnecessarily large tile, and of digging more deeply than is required for good drainage. In Fig. 572 two systems of laying out drains for an area of about 14 acres are represented. By the system A, 625 feet of 4-inch, and 3,020 of 3-inch tile are required, while by that of B only 550 feet of 4-inch, and 2,830 feet of 3-inch tile are needed to do the same work, the lines being 100 feet apart in each case. When long lines of tile are required, three systems of laying have been followed; that of A, Fig. 572, and Figs. 573 and 574. In the case of Fig. 573, covering an area 2,000 feet by 900 feet above the line *a*, there would be required 9,000 feet of 3-inch tile and 9,000 feet of 4-inch with the lines 100 feet apart; but following the B system (Fig. 574), it would be necessary to lay only 3,000 feet of 4-inch tile, with 15,300 feet of 3-inch, with a saving of about $33.

Outlets, junctions and obstructions.

Much care should be taken to secure a clear fall at the outlet of a drain, placing it, if possible, where it will at all times be above water. The last 16 feet of the main should be composed of some material that will neither decay nor be injured by frost. Perhaps the best method is to construct the outlet with portland cement concrete, setting at the mouth in the concrete, as it is made, vertical iron rods close enough together to prevent the entrance of animals at times when it is dry. Ordinary glazed sewer tile answers very well, and cast-iron water pipe makes an ideal outlet, except in the matter of first cost.

Fig. 578. Draining tools. A simple home-made form of water-level at the top, made of iron pipe with water-guage glass in the elbows at the ends.

In joining laterals with the main, three methods are in use: first, special junction tile made at the factory; second, perforating the main on the side with the aid of a tile pick and then fitting the lateral carefully into this; and third, perforating both the main and the lateral, letting the lateral rest on top of the main. When the entrance is made on the side it is important that the lateral enter pointing down stream and forming an angle of about 30 degrees.

Care must be taken that no trees or shrubs whose roots seek running water are permitted to grow near a line of tile through which water runs during much of the growing season. The roots of such trees travel long distances to reach running water and will enter a drain and there branch until, through the arrest of silt, the drain becomes completely clogged. In Fig. 576 are represented the roots of an elm tree that entered a dug well 3 feet in diameter, and grew across to the suction pipe where the vent in it supplied a stream of fresh water whenever pumping was done. In this position they branched and grew, wrapping themselves about the pipe until it formed a mass 10 inches through and more than three feet long. Very many instances are on record where the roots of trees have entered drain tile, and, branching in the manner shown in the illustration, effectually closed them. When it is not permissible to remove the trees, the joints of the tile must be carefully and very firmly bedded in cement mortar.

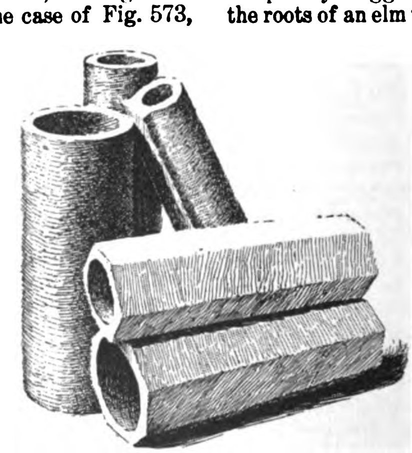


Fig. 577. Forms of common drain tile,—2-inch flat-bottom, 2½- and 4-inch cylindrical, 3-inch hexagonal, 4-inch octagonal.

Draining heavy clay soils.

There are three chief factors which determine the proper distance between underdrains: (1) The freedom with which water may flow through the soil and subsoil toward the drains; (2) the depth at which the drains are placed; and (3) the interval of time between rainfalls sufficiently heavy to produce considerable percolation. It should be clearly understood that it is the character of the subsoil below a depth of two feet, rather than that of the soil, which chiefly determines the rate at which water moves toward and into the drains, and it should be further understood that the subsoil which takes part in the lateral flow of water may be several feet, even 10 or more, below the level at which the drains are laid, provided it is an open sand coarser in texture than the soil itself. When the subsoil is a stiff clay to a considerable depth, 8 to 20 feet, thorough drainage becomes very difficult and expensive because of the fact that lines of tile must be placed relatively nearer together and sometimes even deeper in the ground. There are many regions where the depth of the clay subsoil is so great and the texture of the clay so close that there is no other alternative than to resort to surface drains for longer or shorter periods. Proper tillage and a good system of crop rotation more or less effect a deepening of such clay subsoils by developing a checked or crumbled condition of them, and after this condition has resulted underdrainage becomes more effective.

In cases where the surface 2 or 3 feet and subsoil are comparatively open and underlaid by a close, impervious clay, care should be taken to lay the drains at the proper depth and with the proper distance between them and then to fill the ditch entirely with the open porous surface soil in order to facilitate the entrance of water into the drains.

Cost of underdraining.

The cost of underdraining varies between wide limits, depending on the cost of labor, the cost of tile delivered, the depth and distance apart, and whether natural or artificial outlets must be provided. The cost of 5-inch to 7-inch mains laid 4 to 5 feet deep usually ranges from 90 cents to $1.75 per rod, while 3-inch laterals laid 3 feet deep cost 50 to 75 cents per rod, everything included.

Literature.

The following references include the more important works on drainage: Farm Drainage, by Henry F. French, 1859 and 1884; Land Drainage, by John H. Klippart, 1861; Land Drainage, by Manly Miles, 1892; Practical Land Drainer, by B. Munn, 1855; Drainage for Profit and Health, by George E. Waring, 1867 and 1879; Practical Farm Drainage, by C. G. Elliott, 1882; Engineering for Land Drainage, by C. G. Elliott; Drainage of Fens and Moorlands, by W. H. Wheeler, 1888; Irrigation and Drainage, by F. H. King, 1899; Physics of Agriculture, by F. H. King, Chapters XIV and XV, 1901; Drainage Laws of Indiana, 1903; Drainage Laws of the State of Illinois, 1901; Drainage Laws of Iowa; The Farmer's Handbook Containing Laws of Ohio Relating to Agriculture, 1904; Laws Relating to Construction of Drains (Michigan), 1903.

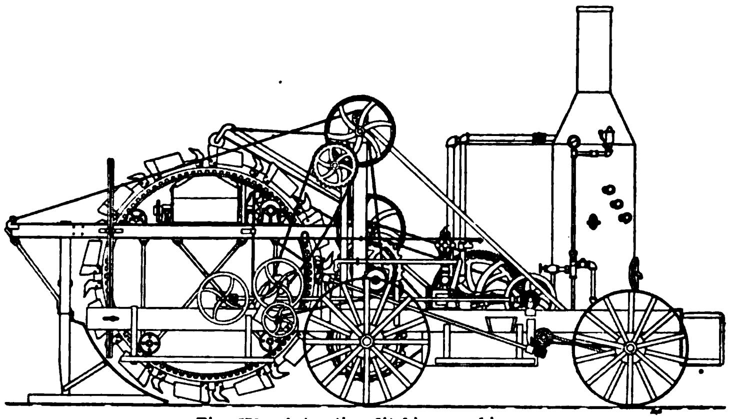


Fig. 579. A traction ditching machine.

IRRIGATION ENGINEERING AND PRACTICE

By *Elwood Mead*

Irrigation is the watering of land by artificial means to enable crops to be grown, or to increase production. In some cases, irrigation is a matter of choice; in others, of necessity. In arid lands like Egypt, the ability to use water in irrigation is necessary to the existence of civilized life. When there is no irrigation, there is desert. Irrigation has its greatest reward in arid lands, but its benefits are not confined to regions of scanty rainfall. Rice is irrigated in Java where the annual rainfall is 8 to 10 feet, and in the United States where the annual precipitation is 40 to 60 inches. In England, Germany, France, Switzerland and Italy, irrigation is highly profitable in districts where irrigated and unirrigated fields, side by side, grow the same crops, and it is extending rapidly in the eastern part of the United States among market-gardeners and growers of crops having a high acreage value.

Nor are the benefits of irrigation limited to supplying the moisture needed by crops. There are large areas of land where the chief benefit from irrigation is the control it gives of temperature. Cranberry marshes are flooded to protect them from frosts. In elevated regions, irrigation lessens the danger from summer frosts. The marcite fields of Italy are warmed in winter and cooled in summer by the thin sheet of water which flows over them. The success of this form of irrigation depends on having warm water, which comes either from springs or the sewage of cities and towns. The same is true of a similar kind of irrigation in Beloochistan. Irrigation is also an effective means of lessening the labor of cultivation and protecting certain crops from the ravages of birds and insects. Rice-fields are flooded at planting to save the seed from being eaten by birds, and later to kill the weeds.

Irrigation is also an important source of fertility. Analyses of the water of the Brantas Delta in Java showed it to contain 0.35 to 0.65 per cent of phosphoric acid, 0.43 to 0.60 per cent of potash, and 0.25 to 0.27 per cent of nitrogen. The soil brought down by the Black Nile and deposited on the lands of Egypt has been the chief factor in maintaining its phenomenal productiveness through a continued and exhaustive system of cultivation for thousands of years. The section of China irrigated from the head waters of the Yellow river has been its granary for ages. Professor Hilgard, Director of the Agricultural Experiment Station of the University of California, estimates that the silt deposited by irrigation, if it is only the thickness of common cardboard, or about $\frac{1}{25}$ of an inch, is equal to two wagon-loads per acre. In many places, the silt deposits are far greater than this. The water of many streams in the southwestern part of the United States often carries 5 per cent of silt. Not all silt deposits are beneficial. There is no fertility in the sand carried down by the glacial streams from the Alps. The tailings from stamp mills have no fertilizing value and often smother young plants. The toxic effects of the poisons carried in the waters from many mills and smelters make it impossible to use these waters in irrigation.

The antiquity of irrigation.

The earliest Egyptian sculptures show water being raised from the Nile in buckets and poured on the thirsty soil. The works along the Nile and the Euphrates have an unbroken historical record which reaches back more than 2,000 years before Christ. The great works of Beloochistan were built by a race whose history is unknown. There are irrigation works in southern India built by the Hindus which antedate the Christian era, while in many parts of the western hemisphere—notably in Peru and the southwestern part of the United States—there are the remains of ancient irrigation works that are evidently centuries older than any historical record. In some countries, irrigation has risen and disappeared with the civilization of which it formed a part. This is true of the irrigation works connected with the Aztec civilization in the western hemisphere. There are evidences of prehistoric irrigation in the Hawaiian islands. Many of the irrigation canals of the Tigris and Euphrates have been abandoned, and few have maintained their ancient importance.

Extent of irrigation.

The countries that have reliable statistics show an aggregate irrigated area of 85,000,000 acres, India having 53,000,000 acres. These statistics do not include Morocco, South and Central America, or any Asiatic country outside of India. The total irrigated territory probably does not much exceed 100,000,000 acres, or a land surface about equal to that of the state of California. The rate at which irrigation is being extended will soon cause a marked change in these figures. More land was irrigated for the first time in the last half of the nineteenth century than in all preceding centuries. The increase in the world's population, the higher standards of living, the improvements in methods of transportation, and the opening up of new markets, are combining to bring about the reclamation of lands hitherto neglected and to increase the productiveness of lands hitherto cultivated. Irrigation is one of the most potent factors in both directions and it is being extended in countries where it has long been practiced, and introduced in countries where it was hitherto unknown.

The area irrigated along the Nile has been doubled in the last fifty years. Four million acres were irrigated from government works in British India in 1850; twenty million acres, in 1900. Although irrigation in Italy dates back to the Roman Empire, the area irrigated has doubled since 1848. Irrigation in Spain dates back to the Moors, yet the area watered at the beginning of the nineteenth century was not half that at its close.

The most significant extension of irrigation, however, has been in newly settled countries. Fifty years ago, less than 100,000 acres of land were irrigated in the United States. Now, over 10,000,000 acres are being irrigated and more than 15,000,000 acres are susceptible of irrigation under completed canals and reservoirs. Within the last twenty-five years, more than a million acres have been brought under irrigation in the northwest territories of Canada, and canals now being constructed will add another million acres to this area. In Australia, New Zealand and South Africa, irrigation has in recent years become an important factor in agricultural production. The government of Japan is extending its use in Formosa. In the ten years ending December, 1901, the government of Java brought approximately one million acres of land under irrigation at a cost of nearly six million dollars.

Division of the subject.

Irrigation is a many-sided subject, but its different relations fall into three general divisions:

(1) Irrigation engineering.
(2) Irrigation practice.
(3) Irrigation institutions.

The first of these includes the determination of the amount of the water-supply and the design and construction of works to render it available.

The second includes the methods of preparing land for applying water, the quantity needed by different crops, and the time and manner of its application to secure the best results.

The third deals with the laws and customs which fix the ownership or control of water-supplies and the business and social relations of water-users to each other and to the public. [This topic belongs with the group of subjects that it is planned to discuss in Vol. IV.]

Each of these has a vital influence on the value of irrigated land and on the peace and prosperity of irrigated states. Each needs to be considered by the student of irrigation, by the settler on irrigated lands, or the investor in irrigation securities.

Irrigation engineering.

Canals. — Irrigation canals and ditches are usually unlined earthen channels. Those that carry water from the place of diversion to the place of use follow, as a rule, the contours of the country. There is not the same freedom of choice in the location of diversion canals that there is with roads and railroads, for, while the gravity canal may drop, it can not rise. Sometimes the governing point in a canal location is the highest point in the land to be watered. But on some streams, the head-gate has to be located where the water can be taken out. When canals cross level country, the land excavated is thrown on both sides and serves to form part of the canal embankment. When the canals run along hillsides, the earth is usually all thrown on the lower side.

The relation of width to depth of canals has been a subject of much discussion with engineers. When conditions permit, the width should be twice the depth, but it is difficult to fix any arbitrary rule, as so much depends on the character of the soil and the slope of the country. There are few canals in which water is carried to a greater depth than ten feet. Beyond this, the danger of breaks from excessive pressure more than offsets economy in excavation. In some of the rice canals, there is no excavation. All the water is carried above the surface of the ground in a channel formed by the throwing up of two parallel embankments, which in some instances are three hundred feet apart.

The grade of canals should be heavy enough to give a velocity which will keep the canal clean and not steep enough to cause it to scour. To succeed in attaining this is not always easy. The heavy clay soils of Wyoming and Colorado will stand twice the velocity of the light ashy soils of the state of Washington. The mean velocity in earthen channels should not exceed three feet per second in canals carrying one hundred cubic feet per second or more, but a mean velocity of three feet per second in a full canal may be reduced to half that velocity when the canal is half full, causing a current so sluggish as to result in its rapid filling by silt. Inasmuch as many canals carry their full flow for a short time only, it becomes a perplexing problem to adjust the grade so as to give the most effective velocity. A sufficient velocity to keep canals clean has also a tendency to lessen the growth of aquatic plants, which is often a serious evil.

Kutter's formula is generally used to compute the velocity of canals. It is:

$$V = \left\{ \frac{\frac{1.811}{n} + 41.6 + \frac{.00281}{i}}{1 + \left(41.6 + \frac{.00281}{i}\right) \times \frac{n}{\sqrt{r}}} \right\} \times \sqrt{ri}$$

in which v equals the velocity in feet per second; i is the sine of the inclination of the slope or the fall of the water surface in a given distance divided by that distance; r is the area of the cross-section in square feet divided by the wet perimeter in lineal feet; n equals the coefficient of friction for different sized channels and channels of different surfaces. The values of n, as determined by recent investigations on American canals, are approximately as follows:

$n=0.0175$ for canals in earth in excellent condition, well-coated with sediment, regular in cross-section, and free from vegetation, loose pebbles and cobbles.

$n=0.020$ for canals in earth, in good condition, lined with well-packed gravel, partly covered with sediment, and free from vegetation.

$n=0.0225$ for canals in earth, in fair condition, the wetted surface being lined with sediment, with an occasional patch of minute algæ, or composed of loose gravel without vegetation.

$n=0.035$ for small ditches having a rough, uneven bed, and for canals in earth in fairly good condition, but partially filled with aquatic plants.

The location of canals in the arid region of the United States is a comparatively simple matter. The mountain ranges give a general direction to the slopes which lie at their base. The rivers that water the plains east of the Rocky mountains have falls varying from seven to fifty feet to the mile. The trend of the country is in two directions—away from the mountains, and toward the streams. If the river has a fall of twenty feet to the mile, and the canal has a grade of two feet to the mile, at the end of the first mile the canal will be eighteen feet above the river and can usually irrigate all of the land between its bed and the stream. Each additional mile increases the difference in elevation and, as a rule, the width of the irrigable strip.

While the location of canals is relatively simple, it is otherwise with their construction. Only engineers familiar with the behavior of arid western soils should be placed in charge of the building of an irrigation canal, because experience is absolutely necessary to taking proper precautions to prevent breaks or excessive seepage losses. Soils that have a large percentage of alkali have a tendency to melt like sugar in water. Gypsum soils are always treacherous material for canal banks. A knowledge of the behavior of these various classes of dissolvable soils is an essential feature in the equipment of the irrigation engineer.

In fixing the carrying capacity of canals, the area of land that is susceptible of irrigation or worth irrigation should be carefully studied. After this, the quantity of water required for the irrigation of an acre should be ascertained and the capacity of the canal based on it. This duty of water should not be fixed by the average requirements of the year, but by the volume needed during the period of greatest use of water. The demands for one month may be double that of any other month, but this month is usually the critical period of the growing season, and a failure to meet crop requirements then means the loss of the year's work. When storage works can be built along the line of a canal to reinforce the supply in times of greatest use of water, the main canal can be much smaller and great economy in construction thereby secured. The value of reservoirs along canal lines to help meet emergency demands is

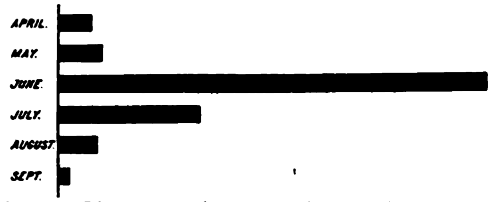


Fig. 580. Diagram showing the relative quantities of water used in the different months of the irrigation season in southern Wyoming, from measurements made on the Laramie river.

shown by the diagram (Fig. 580) of the quantity of water used in the different months of the irrigation season.

In fixing the duty of water (p. 434), the loss from seepage and evaporation in the canal must be taken into account. The allowance for this loss depends on the soil, the care taken in building the canal, temperature of the water and whether clear or muddy, as silt is an important factor in making canals water-tight. Owing to many of the canals in the United States being of recent construction, seepage losses are heavy. On an average, about one-half the water turned into head-gates is lost before it reaches the fields. The following tables give the average results of a large number of measurements of amounts of water turned into canals and turned out into laterals. (Report of Indian Irrigation Commission, Calcutta, 1903):

Average of Seepage and Evaporation Losses from Many Canals in India.

	Per cent
Loss from main canal	20
Loss from laterals	6
Loss from canal crossings	21
Total	47

[1]Comparison of Quantities of Water Turned into Canals with Quantities Turned out Therefrom into Laterals.

Canal and State	Average for canal	Average for laterals from same
	Acre-feet per acre	Acre-feet per acre
Pioneer, Wyoming	8.01	1.41
Amity, Colorado	4.92	1.82
Pecos, New Mexico	7.90	3.69
Bear River, Utah	4.84	1.84
Modesto district, California	13.18	5.76
Turlock district, California	8.34	7.69
Average	7.86	3.70

[1]United States Department of Agriculture, Office of Experiment Stations, Bulletin No. 158, p. 29.

The influence of silt in stopping seepage losses is shown in Italy, where canals from clear streams flowing out of the mountain lakes have to be cemented, while canals taking water from muddy streams do not require this. None of the canals of the Nile have to be cemented. Many of the canals which use the clear artesian water of southern California have to be lined.

Some of the large irrigation canals rank among the world's great engineering achievements. To attempt to describe in detail even the greatest of these would be tedious and hardly intelligible without the aid of working plans. The greatest canal in Europe is the Cavour, which, starting from the Po, crosses the drainage line of many of the largest rivers flowing south from the Alps. It takes water from the glacial streams and supplies water to the foothill streams, and serves as an equalizer of the water-supply over a large part of the irrigable lands of Piedmont. Its works include a stone aqueduct over the Dora Baltea, 656 feet long and 45 feet high, the waterway being 66 feet wide and 12 feet deep. The canal passes under the Sesia river in a masonry siphon 820 feet long and composed of five oval tubes, 16½ feet in their horizontal and 7½ feet in their vertical diameter. All of the works on this canal have the solid and monumental character appropriate to a great national work. Its entire cost, including connected canals, was about $20,000,000.

The Sohagia canal in Egypt, over four thousand years old, is 230 feet wide on the bottom, 278 feet wide on top, and carries 18 feet of water. Its discharge is 15,000 cubic feet per second and it irrigates 340,000 acres of land. The Ibraimia canal supplies water to irrigate over 1,000,000 acres.

Among the large canals built in India by the English government, the Ganges, begun in 1842 and completed in 1855, is perhaps the most noted, although not now the largest. In its operation, engineers have to contend with sudden and destructive floods, which again and again have wrecked its regulating weirs. The Ganges falls 12,000 feet in 180 miles, giving a rapid run-off, and there have been rainfalls of 20 inches in single storms over 1,000 square miles of denuded surface, that caused floods which few works could withstand. When the Ganges canal was built, there was not a railway within a thousand miles. With its laterals, it is 9,900 miles long and its completion with unskilled labor was a great achievement. The canal is 200 feet wide on the bottom and carries water to a depth of 10 feet. It crosses four torrential rivers before reaching the land irrigated. Over one the water is carried in an imposing masonry aqueduct 164 feet wide, of fifteen arches, each with a span of 50 feet. The Ganges system cost $30,000,000. It can carry 11,879 cubic feet per second and has carried 5,700 cubic feet per second. It can be made to irrigate 2,000,000 acres and has irrigated 1,260,000 acres in one year. The average value of the crops grown each year is $27,000,000. The canal's gross revenue is $2,000,000 and the net revenue $1,250,000.

The Chenab canal, begun and completed since

1890, is 250 feet wide on the bottom and carries water 11 feet deep. The main canal is 400 miles long and there are 1,200 miles of secondary canals. It has delivered to irrigators 10,800 cubic feet per second. Its cost was $10,000,000. It can be made to irrigate 2,645,000 acres and has irrigated in one year 2,000,000 acres.

There are no canals in the United States which equal these in size or cost. The largest canal thus far completed is at Twin Falls, Idaho. This is 116 feet wide on the bottom, carries 6 feet of water, and is capable of watering 275,000 acres of land. The Bear river canal of Utah waters, approximately, 100,000 acres and cost over $1,000,000. The Modesto-Turlock canal system of California (Fig. 581) will water, when completed, 275,000 acres and has cost to date $2,850,000.

In the earlier years of canal-building in the United States, engineers had to depart from the models of older countries. Lumber and earth were cheap; masonry, iron and cement were dear. The cheap materials were used. (Fig. 582.) More permanent structures of masonry and iron are now needed and they are being built. The construction of government works under the national Reclamation Act has made it possible to give more attention to permanence than to first cost, and this is being done, the head-gates on the recently-completed government canal near Reno, Nevada, being a fine example of concrete construction. The following table gives the estimated cost of several of the government works now being built:

PROJECTS NOW UNDER CONSTRUCTION.

State.	Projects.	Amount set aside for beginning construction.	Acres Irrigable.
Arizona	Salt River	$3,600,000	180,000
California and Arizona	Yuma	3,000,000	85,000
Colorado	Uncompahgre	2,500,000	125,000
Idaho	Minidoka	1,300,000	60,000
Montana	Huntley	900,000	35,000
Montana and North Dakota	Fort Buford	1,800,000	60,000
Nebraska and Wyoming	North Platte	3,500,000	100,000
Nevada	Truckee-Carson	2,740,000	100,000
New Mexico	Hondo	280,000	10,000
South Dakota	Belle Fourche	2,100,000	80,000
Wyoming	Shoshone	2,250,000	125,000

PROJECTS APPROVED BY THE SECRETARY OF THE INTERIOR.

Oregon and California	Klamath Falls	$1,000,000	236,000
Oregon	Malheur	2,250,000	100,000
Montana	Milk River	1,000,000	200,000
North Dakota	Bismarck	....	15,000
Pumping	Buford-Trenton	550,000	18,000
Washington	Palouse	2,800,000	80,000
Idaho	Payette-Boise	1,300,000	250,000

The total sum set aside for all classes of projects is $34,270,000, and the amount of land to be irrigated is 1,909,000 acres.

Reservoirs.—Reservoirs have two functions. One is to hold back storm waters or the discharge of streams that would run to waste in non-irrigation periods. The other is to reinforce canals at times when use in irrigation is greatest and the demand beyond the canal's capacity. The most important use is the first, that is, to serve as regulators to the run-off, holding back water till it is needed.

The value of reservoirs varies greatly in different countries. When rivers carry their greatest discharge when use in irrigation is greatest, there is least need of storage. Rivers rising in lofty snow-clad mountains come nearest doing this. The glaciers of the Alps serve as an automatic regulator

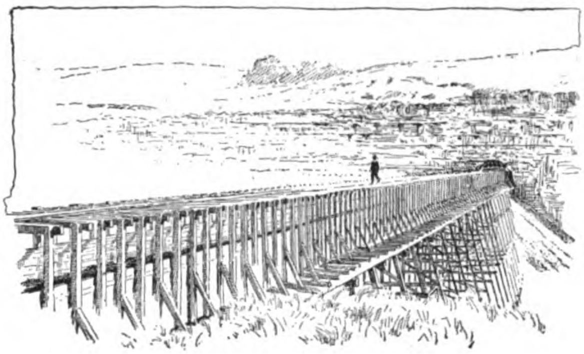


Fig. 581. Flume and tunnel, Modesto canal, California.

for irrigation below. The hotter the season, the faster the glacier melts and the more water runs down to farmers. Forests are also a natural reservoir, as they tend to hold back the mountain run-off. There are few streams, however, where a certain amount of storage is not required, and none where all the water can be used without some regulation. The flow of the Nile in September is 35 times that in June. Only a small fraction can be utilized by direct diversion. The storage works, built or projected, will greatly extend the irrigation possibilities of this river. The Assuan reservoir is the greatest of these. The water above this dam is 66 feet deep and the reservoir extends up the stream 100 miles and holds 38,000 million cubic feet of water.

In the arid region the greatest discharge of rivers comes as a rule in June. This answered fairly well for direct irrigation when wheat and oats were the chief crops, but with the growing of higher-priced products, like sugar-beets and potatoes, more and more water is needed in August and September. In these months the snows are melted and rivers are low. The Poudre river in Colorado, where potatoes and sugar-beets are the principal crops, has an average flow of six times as much water in June as in August, while the high water of June is thirty-two times the low water of August. Without storage, only a small fraction of the stream could be used for growing the most profitable crops of that district. Over 100 reservoirs have been built in this valley to furnish water for late irrigation.

Two things are contributing to make reservoirs of constantly increasing importance to the irrigation development of the United States. One is that the area irrigated by direct diversion is controlled by the low-water flow, and on many streams this is now all utilized. The other is the increase in the area devoted to crops requiring irrigation in the late summer. A diagram of the flow of the Boise river (Fig. 583) shows that without storage the greater part of its annual discharge has run off before the irrigation of potatoes begins. The Office of Experiment Stations, of the United States Department of Agriculture, has for several years conducted extended measurements to ascertain the quantity of water used in irrigation in each of the summer months, and has compared that with the flow of streams in order to determine the quantity that would have to be stored to bring the run-off and use into complete agreement. The table below gives the result of these studies in three valleys where irrigation is required. From this it will be seen that during five months of the year, unless the water is stored, it will all run to waste:

Fig. 582. A rock and brush irrigation dam in the Milk river valley, Montana.

Percentage of Annual Flow of Rivers Discharged Each Month.

Month	Yakima river, Washing'n	Gallatin river, Montana	Boise river, Idaho
	Per cent	Per cent	Per cent
January	7.8	3.8	5.5
February	7.1	3.4	2.7
March	4.7	3.6	3.9
April	7.1	3.8	14.5
May	13.8	6.6	20.8
June	19.1	29.1	25
July	13.2	24.7	12.2
August	4.7	7.1	3.7
September	2.4	4.8	2.4
October	2.4	4.7	2.9
November	6.3	4.4	3.1
December	11.4	4	3.3
Total	100	100	100

Percentage of Flow of Canals During Irrigating Season Discharged Each Month.

Month	Sunnyside canal, Yakima river	Middle Creek canal, Gallatin valley	Rust Lateral Ridenbaugh canal, Boise river
	Per cent	Per cent	Per cent
April	5	. .	3.2
May	12.8	. .	17.5
June	14.4	29.8	17
July	20.1	39.9	14.6
August	23	20.7	18.6
September	13.3	9.6	16.7
October	11.4	. .	12.4
Total	100	100	100

The different studies thus far made show that 30 to 60 per cent of the water must be stored to permit of the complete use of western rivers. The following diagram (Fig. 583) shows the time when the water would run to waste if not stored, and when it would be used if impounded.

In their location, reservoirs fall into two classes: those in the channels of running streams and filled by the stream flowing in and through them, and those outside stream channels and filled from canals. The latter are less subject to damage from floods, and less liable to be filled by silt.

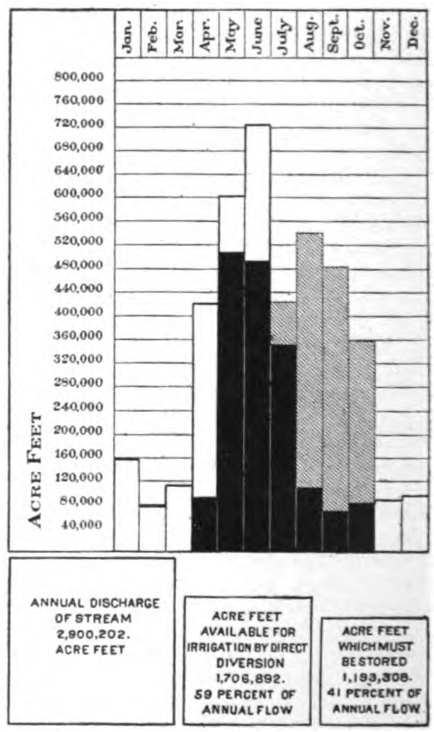


Fig. 583. Diagram showing flow of Boise river, Idaho, and storage required for its complete use in irrigation. White areas represent quantity of flow during non-irrigation period. Black areas represent amount of flow which could be used by direct diversion. Shaded areas represent the volume which must be stored and the time of its use.

On muddy streams the life of reservoirs is limited by the rate of sedimentation. Hundreds of reservoirs in India have been abandoned because it was cheaper to build new reservoirs elsewhere than to clean out old ones. The same is true of the reservoirs built by the Moors in Spain. When the forests were cut off the Pyrenees, the rapid erosion of the exposed mountain sides soon filled them and ended their usefulness.

The existence of lakes, like Yellowstone Lake in the channel of the Yellowstone river and Lake Tahoe in the channel of the Truckee river, would indicate that there is little danger of sedimentation in the canals of mountain streams in the United States. These lakes have been little reduced in size by the sedimentation of centuries. The fact that all the lakes in the channels of plains rivers are filled would indicate that this action may be feared in reservoirs there, and their construction should include some provision for cleaning out. As yet no comprehensive studies have been made of the rate of silting up of reservoirs in this country. The reservoir in the Colorado river at Austin, Texas, was completed in 1893. Measurements made in 1900 showed that 48 per cent of the reservoir had been filled. Measurements on many of the Colorado reservoirs outside of stream channels show that the rate of sedimentation is so slow that it will require centuries to fill them up.

Nine and a half million acres are irrigated from reservoirs in India, of which there are over 90,000. Sixty thousand of these are in Madras, and it is estimated that the combined length of the impounding dams, if placed end to end, would reach one and a half times around the globe. The majority of these reservoirs are small, but one now being built will store 870,000 acre-feet.

In Ceylon there is a short period of excessive rainfall and a long season of drought which renders irrigation a necessity. The amount of rain that falls during the monsoon is startling; often 9 to 12 inches falls in 24 hours, and 8 inches a day has fallen for four consecutive days. The average rainfall at the coast is 89 inches; at 2,000 feet elevation it is 217 inches. As this falls and runs off in a brief period, irrigation is chiefly based on storage. The magnitude of these reservoirs is not surpassed by any other similar works, ancient or modern. The Padival dam is 11 miles long, 200 feet wide at the base, 30 feet wide at the crest, and 70 feet high in places. It cost $6,327,100.

The Kalawewa reservoir has an area of 6,000 acres. The dam is 12 miles long, 60 feet high. Another embankment is 40 to 90 feet high for a distance of 24 miles. Some of these reservoirs date from 500 years before Christ. One of the kings of the twelfth century built 1,470 and repaired 2,355 reservoirs. Of the 5,000 reservoirs now in use in Ceylon, nine-tenths are reconstructions of works built ages ago. During the time that these works were allowed to fall into disuse, the population decreased from 5,000,000 to 750,000.

Several hundred reservoirs have been built as private works in the arid states. Nearly all are small, covering 5 to 100 acres. A few cover 1,000 to 10,000 acres and have costly dams and waste-ways.

Pumping water for irrigation.—The lifting of water from wells or streams for use in irrigation is more expensive than the distribution of water from canals and reservoirs by gravity. However, it has certain advantages which go far to compensate for the increased outlay. There are no controversies with other canals over the water of the stream, nor friction with other irrigators about the management of the ditch and laterals. The farmer who pumps his own supply can control with certainty the time when he begins and ceases watering his fields.

In many localities, underground waters are the only source of supply. This is true of large areas in the West where surface streams disappear, being swallowed up in the broad, sandy channels of the river valleys. The increased importance of underground water-supplies, and the value of streams that can not be diverted by gravity, have greatly extended the field of pumping in recent years and has brought about improvements in pumping machinery that have made it both simpler and cheaper to operate.

About three-eighths of the water used in Egypt is either lifted from canals or from the Nile. Many of the Egyptian canals have been planned to require the water to be lifted out of them, rather than to run out by gravity, because labor is cheap and it is believed to induce economy in the use of water.

In the United States more than 200,000 acres are irrigated by pumps in California, and more than 400,000 acres in the rice districts of Louisiana and Texas. In all, about 750,000 acres are irrigated from pumps, and as nearly all this land is devoted to the growing of high-priced products, it is probable that nearly 10 per cent in value of the irrigated products of this country is produced with pumped water.

Thirteen million acres are irrigated from wells in India. This is more than one-fourth of the entire irrigated area and more than the total area irrigated in the United States. The following table gives the number of wells, the area irrigated, and the average area irrigated from each well in the different provinces of India. (Report of Indian Irrigation Commission, Calcutta, 1903, p. 48):

Province	Number of wells	Area irrigated	Average area irrigated per well
		Acres	Acres
Punjab	349,000	3,750,000	10.7
United Provinces	1,330,000	5,731,000	4.3
Madras	626,280	*2,000,000	3.2
Bombay	254,000	650,000	2.6
Central Provinces	56,000	77,000	1.4

*Includes the area irrigated from tanks assisted by wells.

The pumping machinery is of the simplest possible character. Pumps operated by hand power and wheels run by cattle are the prevailing types. A large wheel may require four or even six teams of oxen, with two and sometimes four oxen to a team. The usual type of pump, when cattle are used, is the Persian wheel, or the well-known water-bag. When manual labor is used, water is lifted by means of leather buckets raised by means of a wheel, or the weighted well-sweep used in Egypt.

There is one pumping station in Italy that lifts water 90 feet for the irrigation of 7,000 acres of land, and another pumping station that serves to irrigate about 5,000 acres of land.

The costliest and probably the most efficient pumping machinery used in irrigation is found on the sugar plantations of the Hawaiian Islands. Some of these pumps lift water 650 feet, and the average lift is over 300 feet. Five plantations on Oahu pump 287,000,000 gallons a day from 195 wells, the combined capacity of the pumps being 11,847 horse-power. On Maui, 140,000,000 gallons are pumped daily by engines having a combined capacity of 6,954 horse-power, and on Kanai 55,000,000 gallons are pumped daily by engines having a combined capacity of 2,033 horse-power. In installing these pumps, the boilers and fuel are on the surface of the ground; the pumping machinery is put as near the water level as possible, being in cement-lined chambers often three or four hundred feet below the earth's surface. The water-supply for these large pumping stations is usually brought together in a sump from wells 12 inches in diameter, spaced 50 feet apart, and connected by pipes of somewhat larger diameter. As a rule, ten such wells will supply 10,000,000 gallons daily to a pumping station, and a 10,000,000-gallon pumping engine, lifting water 300 feet, expends $120 a day for fuel.

Cost of pumping.—The most primitive pumping machinery used in irrigation is found in Egypt and India, and the simplest of these is the shaduf. Its form and method of operation are shown Fig. 584. It consists essentially of two upright posts with a cross piece, and a pole with a bucket hung at one end and a counter weight of mud on the other, which is operated after the fashion of the old well-sweep. The bucket is usually made of leather, stiffened at the top by a wooden hoop, and holds about a third of a cubic foot. A single shaduf can lift water only 5 or 6 feet, but they are installed in a series of three or four, which, working together, lift water 20 to 30 feet. One person will lift about 3 cubic feet of water a minute. A man usually works two hours at a time, and two men working together will operate one 10 hours a day, one machine lifting 1,800 cubic feet of water. Assuming that an irrigation requires an inch of water, a device of this kind would irrigate about a half acre a day. The following table gives the statistics of the cost of irrigation by means of shadufs in Egypt. (United States Department Agriculture, Office of Experiment Stations, Bulletin No. 130, p. 41):

EFFICIENCY OF THE SHADUF AS A WATER-RAISING DEVICE.

Height of lift	Number of shadufs in series	Cost of running machines per day of ten hours	Area irrigated in ten hours	Cost per acre each irrigation	Discharge per day	Area of field irrigated	Cost per acre for each foot of lift
			Acre		Area-foot	Acres	
2.8 feet	1	$0 30	0.21	$1 43	0.06	0.98	$0 51
3.3 feet	1	32	.17	1 88	.06	1.21	57
3.3 feet	1	30	.19	1 58	.07	1.48	48
3.9 feet	1	30	.19	1 58	.05	1.40	41
4.2 feet	1	29	.15	1 93	.05	.91	46
5.7 feet	1	30	.18	1 67	.06	1.15	29
5.8 feet	1	30	.12	2 50	.04	1.13	43
9.1 feet	1	35	.12	2 92	.05	1.09	32
10.4 feet	2	66	.10	6 60	.03	1.01	63
15.8 feet	2	65	.10	6 50	.03	.96	41
19.3 feet	2	60	.09	6 67	.03	.96	34
19.4 feet	3	95	.10	9 50	.03	.81	49
21.5 feet	3	86	.08	10 75	.03	1.02	50
22 feet	3	90	.08	11 25	.03	.85	51
29 feet	4	1 23	.08	15 37	.03	.77	53
29 feet	4	1 39	.08	17 37	.03	.80	60

The sakiyeh is a lifting machine in which cattle take the place of man as a motive power. Of these there are probably 50,000 in Egypt. The machine consists of a horizontal wooden wheel 10 feet in diameter, with cogs in its circumference which engage similar teeth on a vertical wheel, the shaft of which passes to a second vertical wheel carrying buckets in which the water is lifted. The power is supplied by an ox or a buffalo hitched to a sweep on the horizontal wheel. One animal works two three-hour periods a day. These machines will lift 120 to 180 cubic feet of water per hour, depending on the lift. For lifts of 12 feet, the cost of each irrigation is about $1.50 an acre. For 18 feet, it will reach $2.50 an acre, and for 20 to 30 feet, $3 or $4 an acre. In recent years, a large number of steam pumping plants have been introduced in Egypt, which furnish water for about $1.90 an acre for each irrigation when the lift is not over 10 feet. Cotton has to be watered five times during the growing season, making the cost about $10 an acre for water.

The cost of pumping water in India, as given in official reports, includes interest charges on the cost of the well and the expenses of operation. It is hazardous to attempt to give an average of the

Fig. 584. The shaduf, used for raising irrigation water in Egypt.

cost of wells, the variations are so great, but the average cost of a permanent well in Gujerat is about $300; in Punjab and the United Provinces, $150; and in the Central Provinces, about $175. The cost of a permanent well in northern India is about $20 per acre served: and in southern and central India, about $50 per acre. The average lift of water from these wells is about 30 feet, and the cost of lifting water for the irrigation of wheat, about $3.50 an acre per year. From this it rises to as high as $30 an acre per year for the irrigation of rice and garden products.

The cost of pumping water in Piedmont, where the lift varies from 20 feet at the lower end of the tract to 70 feet at the highest part, averages $5.80 an acre. There is no fuel cost connected with this, the pumps being operated by water-power costing nothing.

During the past two years, the division of Irrigation and Drainage Investigations of the United States Department of Agriculture has made extended studies of the cost of pumping water in the United States. These tests have included rotary, centrifugal and piston pumps, wood, coal and crude oil as fuel for steam plants, gasoline and distillate in gas engines, and electrical power — the latter being transmitted in some instances 240 miles. In the Santa Clara valley, California, records were obtained of the annual cost of irrigation from 60 pumping plants. The average depth of irrigation was 1.13 feet, or 1.13 acre-feet for each acre irrigated. When water was sold by the owner of pumping plants, the average charge was $13 an acre-foot, making the cost for water per acre $14.69. The average cost of fuel and repairs in pumping water was $4.96 an acre, the fixed charges of interest and the like were estimated at $5.20 an acre, making the average cost of pumping water, to the owners of pumping plants, $10.16 an acre. Tests were also made of the efficiency of pumping plants and of pumps. The field tests show an average efficiency of 41.17 per cent, the minimum being 26 per cent and the maximum 65 per cent.

Eight plants using gasoline for fuel, and varying in size from 5 to 21 horse-power, showed an average fuel cost for each foot of lift of an acre-foot of water of 4.5 cents. Three steam plants, using crude oil for fuel, showed an average cost for this lift of 2.8 cents. The average size of gasoline plants is 10 horse-power; the average size of steam plants, 21 horse-power. The cost, therefore, varied approximately with the size of the pumps.

The results of these tests show, first, that the larger the plant, the more effective the work. This holds for both engines and pumps. Second, that the engine and pump should carry a full rated load to do their best service. Third, that if possible, the engine and pump should be directly connected. Fourth, suction and discharge pipes should be large, with the fewest possible number of bends.

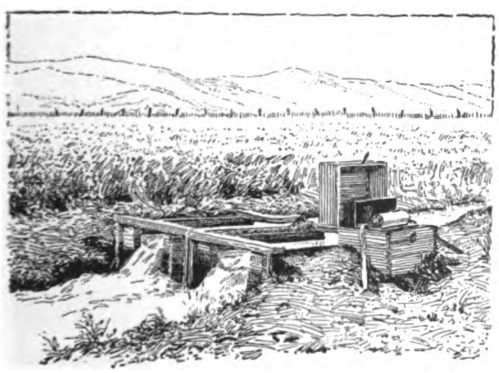


Fig. 585. Weir on a lateral ditch in the West.

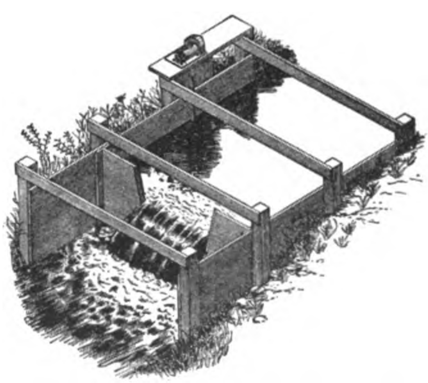


Fig. 586. Cipolletti weir, with water register in place.

Fifth, care, cleanliness and intelligence in operation are the most important factors. Sixth, a low suction lift and a free check or foot valve are desirable but minor features.

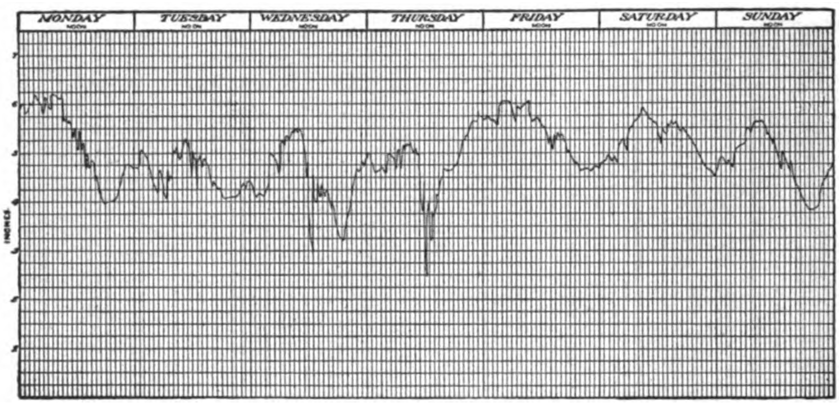


Fig. 587. Copy of sample water register sheet.

For convenience, electricity is the best power. Gasoline costs little for attendance but requires intelligent management to avoid a large bill for repairs. For a large pumping station, steam is most economical, and the cost of operating steam plants has been greatly reduced by the discovery of crude oil in California and Texas.

The statistics of irrigation by pumping in New Mexico in 1904 showed an average cost per acre-foot of water lifted of $3.44, and the quantity of water used on an acre varied from 2 to 5 feet. The lifts varied from 10 to 40 feet. In southern Texas the average depth of water used in irrigation from pumping plants was 2.67 acre-feet to the acre, and the average cost per acre $14.79, the cost varying with the fuel and size of the pumps, oil being the cheapest fuel, and wood next cheapest.

Water for irrigation is lifted at less cost per foot in the rice districts of Louisiana than in any other part of the United States. Tests in 1904 showed that the cost of lifting an acre-foot of water one foot varied from .9 cent to 2.4 cents. The large size of these plants explains their increased efficiency over those of California.

Windmills are largely used in the United States for lifting water for domestic purposes, and are beginning to be used for irrigation. There would seem to be a large field for their profitable employment. Tests made of American-built windmills in India led to the conclusion that both the support and the mill are too lightly made for the hard and continuous service which pumping water for irrigation requires.

The largest areas in the United States irrigated by windmills at present are to be found in southern Kansas and in the vicinity of Stockton, California. The annual average cost of windmill irrigation for maintenance, repairs and care at Garden City, Kansas, is about $2.35 for each acre irrigated. The life of these mills, however, is so brief and the expense of their installation so large as to make windmill irrigation at present fully as expensive per acre as that from gasoline or steam engines. With stronger and larger mills, it is believed the cost will be greatly reduced.

Irrigation practice.

The measurement of water.—The great extent of land now being irrigated makes the measurement of water an important feature of irrigation practice. During the past quarter of a century, engineers in India, Italy and the United States have been especially active in securing records of the flow of streams used in irrigation, and working out methods for securing accurate gaging and records of the flow of streams. This information is needed to determine the area that can be watered, and to know how much water belongs to each canal. The value of water has increased enormously with the extension of its use in irrigation, and this makes its accurate measurement and orderly division far more important than formerly. The gaging of private canals and the preparation of tables which show their flow at different depths, is done by government officials in many of the western states and in most other countries. This work is done by the state as an aid to securing accurate and important data for the division of streams between

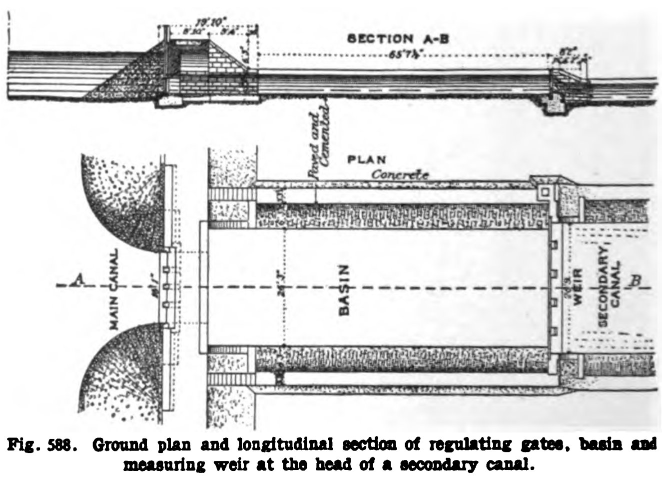


Fig. 588. Ground plan and longitudinal section of regulating gates, basin and measuring weir at the head of a secondary canal.

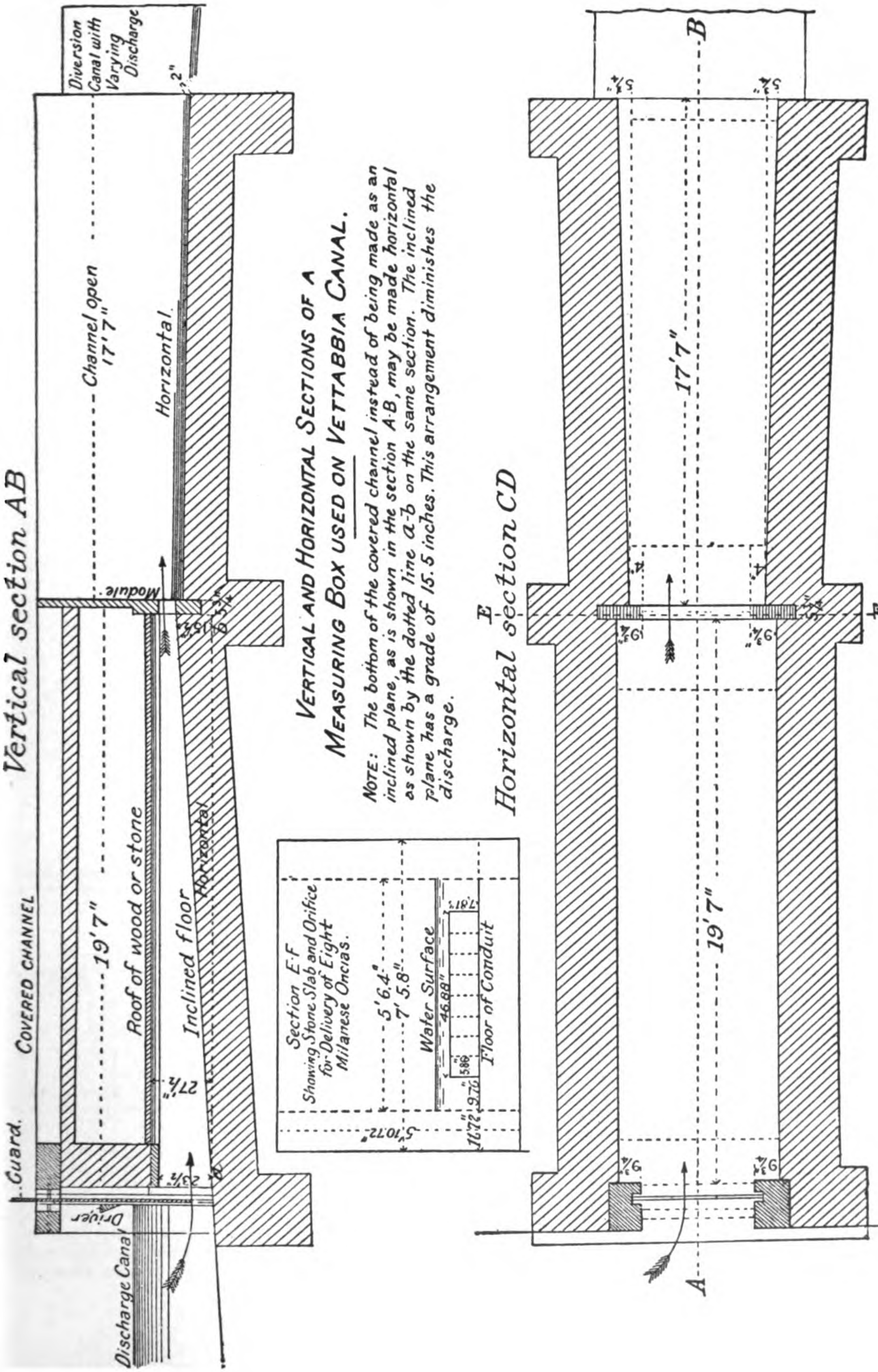


Fig. 589. Structural details of a measuring device.

canals, and many companies measure water to consumers.

In gaging rivers, the cross section is measured; then the mean velocity of the flow determined either with some form of current meter or floats. This gives the data for computing the discharge. By repeating these measurements when the river is at different stages, a table of discharges at different depths can be prepared by interpolating between the points where measured.

In many countries it is required by law that canals be equipped with measuring flumes near the head gates where the velocity is measured. This facilitates securing an accurate mean velocity and the computation of discharges. On some canals, weirs are used instead of flumes. Some of the larger Italian canals have costly stone weirs with knife-edged iron crests. The weir is accurate only in streams carrying little silt. In muddy streams sediment is deposited above the weir, making the result differ from the tables of weir discharges. Fig. 585 shows a weir on a lateral ditch in the West. Fig. 586 shows more plainly the construction of the weir, which was invented by an Italian —Cipolletti—whose name it bears.

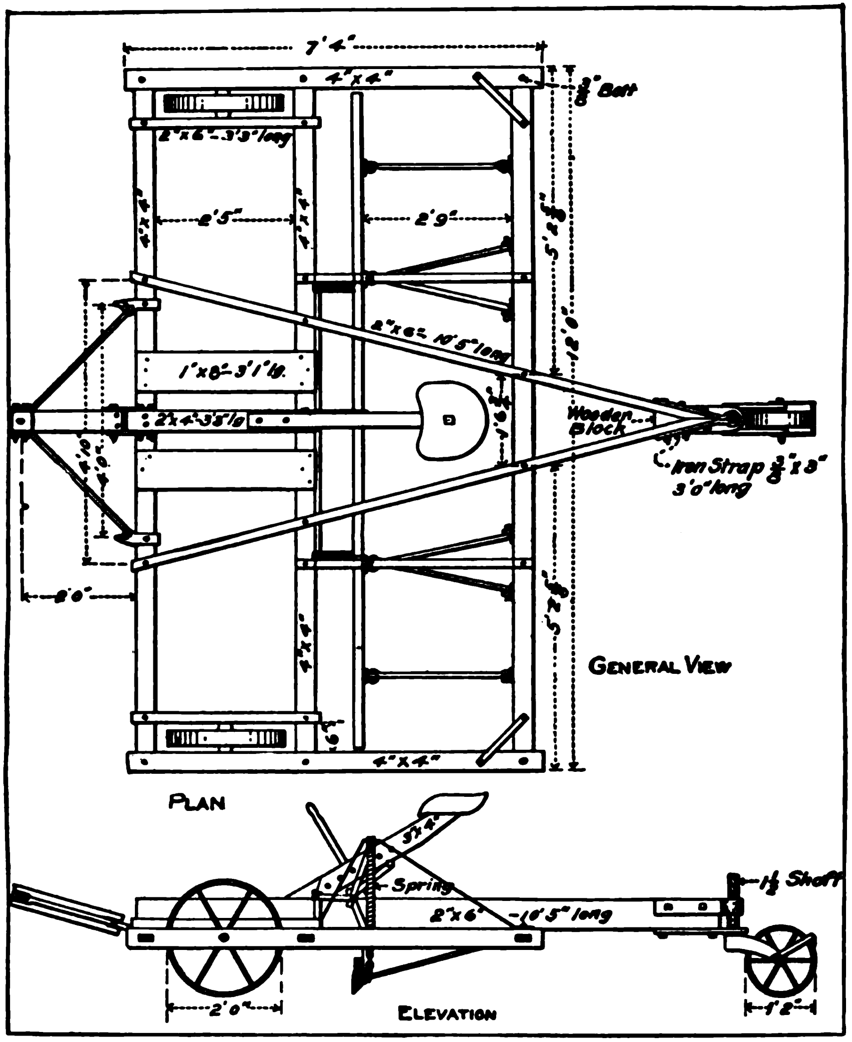


Fig. 590. Details of the construction of a leveler, for use in preparing a field for irrigation. (Page 432.)

To secure accurate results, weirs should have a horizontal crest, which is placed perpendicular to the axis of the stream. The upstream edge of both the crest and sides of the weir must be sharp, and the distance from the sill of the weir to the bottom of the canal must be three times the greatest depth of water passing over the weir, and the distance from the ends of the weir to the sides of the canal must be not less than twice the greatest depth of water flowing over it. The sides of the weir may be either vertical or inclined. If inclined, the horizontal distance should be one-fourth that of the vertical. The formula for computing the quantity of water flowing over a weir with inclined sides is: Q equals $3.36Lh^{\frac{3}{2}}$, in which Q equals the volume of water, L equals the length of the weir, and h equals the depth of the water flowing over the weir. With vertical sides, the formula is: Q equals $3.33\ (L\text{-}0.2h)h^{\frac{3}{2}}$. With both streams and canals, records are kept of variations in depths, either by frequent reading of gage rods or by means of electrical or clockwork recording instruments.

Measuring water used by irrigators.—Much of the water supplied to irrigators is charged for by the area irrigated. The defect in this system is that it does not encourage economy in the use of water, but rather the reverse. On the other hand, if the irrigator's charges for water are based on the volume he uses, his skill and economy bring a direct reward in lessened water bills. Hence, in theory at least, the true method of charging for water is for the quantity delivered, measured at the head of the irrigator's lateral. This has not been done because of the mechanical and agricultural difficulties which stand in the way of distribution based on charges by volume. For many hundred years, inventors have sought some automatic device which would deliver a fixed volume of water regardless of the varying depths in the supply channel, but the practical difficulties in the way of this have not been wholly surmounted.

The meter and the module are both used to measure water in irrigation. The meter measures mechanically the volume delivered, exactly as it does water for domestic uses in towns or as gas and electricity are measured. The module regulates the quantity delivered and thus gives a basis for computing the quantity supplied. The meter is inapplicable to large canals, because the cost of meters of sufficient capacity to deliver the volume desired would be prohibitive, and because the fall needed to give a working pressure can seldom be had. Therefore, in countries where water is charged for by the volume, a module rather than a meter has been the means of measurement employed.

The volumetric measurement of water has been brought to the greatest perfection in Italy, where the inequalities in the quantity of water furnished irrigators led to a struggle lasting over 200 years, culminating in the adoption of the module of Soldati. (Figs. 588 and 589.)

In this an effort is made, by means of the headgate at the upper end of the box, to regulate the pressure on the top of the orifice, and when visited with sufficient frequency by the ditch-tenders the results are approximately correct.

The American counterpart of the Italian oncia, the unit of the Italian module, is the inch, which is used in measuring water for both irrigation and mining. It is the volume of water which will flow through an inch square orifice, under a prescribed pressure that varies from 4 to 8 inches above the top of the orifice. In the United States the larger

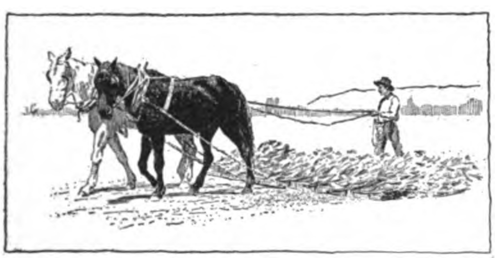


Fig. 591. Brushing in alfalfa seed before irrigating.

orifices are 6 inches in height and of sufficient width to give the required number of inches.

The measurement of water through orifices has several advantages. It is convenient. Men who have no knowledge of hydraulics can understand it and know whether or not they are getting the volume paid for. It is, however, limited to the measurement of small quantities of water and is never of more than approximate accuracy. The weir, used in connection with a clockwork or electrical register which keeps a constant record

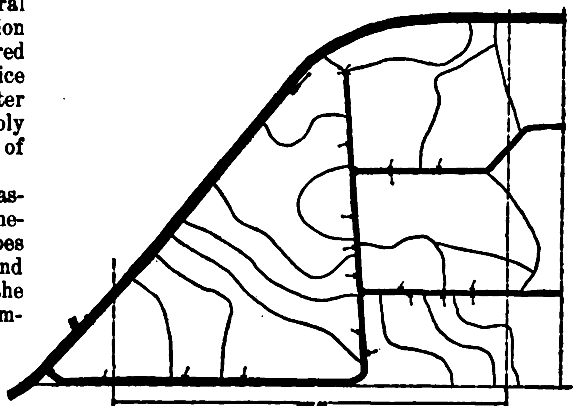


Fig. 592. Irrigation by contour check system. (Page 433.)

of the depth flowing over the crest, has been largely used, and when weirs are properly placed this record gives the most correct measurement of the quantity delivered that can be had, as it is independent of the fluctuations in the depth over the weir. Fig. 586 shows a Cipolletti weir with a clockwork recorder, and Fig. 587 a record sheet taken from this recorder. These are also used for recording the depth of water flowing in flumes.

Units of measurement.—In the measurement of water in irrigation, the primary unit of English-speaking engineers is the foot; of practically all other engineers, the meter. The cubic foot per second is the common English unit of measurement of flowing water, and the liter per second the unit of other countries. In considering the use of stored water, or in discussing the duty of water, the acre-foot or the acre-inch—meaning the depth of water over an acre of land—has the advantages of accuracy and of being easily understood. In computing the cost and work done in pumping water, the height of the lift becomes a factor, and foot-gallon, foot-cubic-foot, and foot-acre-foot are terms frequently used.

The different modules used in measuring water give rise to an almost unending number of units. The relation of the miner's and irrigator's "inch" to the cubic foot per second has been defined as follows in a number of the western irrigation states:

Colorado,	one cu. ft. per sec. equals	38.4	statute inches.
Montana,	one cu. ft. per sec. equals	40	statute inches.
Idaho,	one cu. ft. per sec. equals	50	miner's inches.
Arizona,	one cu. ft. per sec. equals	40	miner's inches.
Nevada,	one cu. ft. per sec. equals	50	miner's inches.
Utah,	one cu. ft. per sec. equals	50	miner's inches.

Differences in units of volume render it difficult to compare the results of irrigation practice in different countries, as is shown in the following table of equivalents of units employed in Italy alone:

TABLE OF EQUIVALENTS; ITALIAN UNITS FOR WATER MEASUREMENTS.

Units in use in various provinces in Italy	Cubic feet per second	Italian module	Albertini module	Wheel of F. D. Michelotti	Oncia of Ignazio Michelotti	Oncia of Caluso	Oncia of Milan
Italian module	3.5315	1.0000	1.7241	0.2986	3.4650	4.1841	2.8985
Albertini module	2.0482	.5800	1.0000	.1732	2.0097	2.4267	1.6811
Wheel of F. D. Michelotti	11.8233	3.3480	5.7724	1.0000	11.6008	14.0083	9.7043
Oncia of Ignazio Michelotti	1.0192	.2886	.4975	.0862	1.0000	1.2073	.8365
Oncia of Caluso	.8440	.2390	.4120	.0713	.8281	1.0000	.6927
Oncia of Milan	1.2183	.3450	.5948	.1030	1.1954	1.4435	1.0000
Oncia of Novara	1.2752	.3611	.6225	.1078	1.2512	1.5107	1.0466
Oncia of Pavia	.6886	.1950	.3362	.0582	.6756	.8159	.5652
Oncia of Lodi	.6198	.1755	.3025	.0524	.6081	.7340	.5086
Oncia of Crema	.6374	.1805	.3112	.0539	.6254	.7552	.5231
Oncia of Cremona	.7183	.2034	.3506	.0607	.7047	.8510	.5895
Quadretto of Verona	5.1332	1.4536	2.5062	.4341	5.0367	6.0820	4.2133
Quadretto of Mantua	11.1005	3.1433	5.4194	.9388	10.8914	13.1518	9.1110
Mole of water or rodigio	7.3100	2.0700	3.5689	.6182	7.1724	8.6610	6.0000

Units in use in various provinces in Italy	Oncia of Novara	Oncia of Pavia	Oncia of Lodi	Oncia of Crema	Oncia of Cremona	Quadretto of Verona	Quadretto of Mantua	Mole of water or rodigio
Italian module	2.7693	5.1282	5.6980	5.4001	4.9164	0.6872	0.3181	0.4831
Albertini module	1.6062	2.9743	3.3048	3.2127	2.8515	.3990	.1845	.2802
Wheel of F. D. Michelotti	9.2716	17.1692	19.0769	18.5484	16.4601	2.3032	1.0651	1.6314
Oncia of Ignazio Michelotti	.7992	1.4800	1.0644	1.5988	1.4188	.1985	.0918	.1394
Oncia of Caluso	.6618	1.2256	1.3618	1.3240	1.1745	.1644	.0760	.1198
Oncia of Milan	.9554	1.7691	1.9658	1.9113	1.6961	.2373	.1097	.1666
Oncia of Novara	1.0000	1.8517	2.0575	2.0005	1.7753	.2484	.1148	.1744
Oncia of Pavia	.5400	1.0000	1.1111	1.0803	.9587	.1341	.0620	.0942
Oncia of Lodi	.4860	.9000	1.0000	.9722	.8628	.1207	.0558	.0848
Oncia of Crema	.4998	.9256	1.0284	1.0000	.8874	.1241	.0574	.0872
Oncia of Cremona	.5632	1.0430	1.1589	1.1268	1.0000	.1399	.0647	.0983
Quadretto of Verona	4.0254	7.4543	8.2826	8.0538	7.1465	1.0000	.4624	.7022
Quadretto of Mantua	8.7047	16.1194	17.9105	17.4144	15.4537	2.1624	1.0000	1.5185
Mole of water or rodigio	5.7324	10.6153	11.7948	11.4681	10.1769	1.4240	.6585	1.0000

Preparing land for irrigation.—The cost of preparing land for irrigation involves the removal of sage-brush or other growth, and plowing, harrowing and grading the surface so as to permit of its even watering. This cost varies largely with irregularities of the ground, price of labor, and the nature of the growth to be removed. Sage-brush can be removed by hand for $1.50 to $3 an acre, or by machines for somewhat less. Plowing will cost $2.50 to $4 an acre. No average can be made of the cost of grading and leveling. The devices used in this run from many home-made tools to costly patented scrapers and graders. One of the land-graders used in the West is shown in Fig. 590. It is 12 feet wide, 7 feet long, and has an adjustable steel-shod share 11 feet 2 inches long and 9 inches deep. This instrument, operated by four horses, will level 10 acres a day if the inequalities are small. In California the favorite implement in leveling ground is the buck scraper. The seed-bed may be prepared very inexpensively, as suggested in Fig. 591.

The cost of preparing land for irrigation in the United States varies from $3 to $30 an acre. The first cost, however, is often offset by the lessened cost of applying water. The following gives the result of adding together the averages of the first cost and the cost of applying water for the first five years, of a large number of examples:

Check method	$3 60
Flooding	2 75
Furrow method	3 50
Basin method	4 50

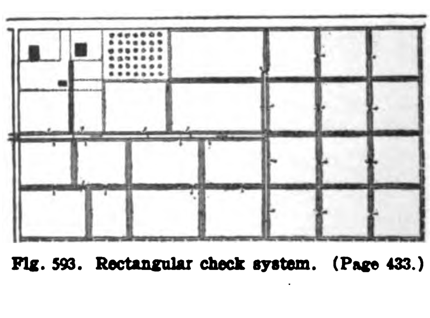


Fig. 593. Rectangular check system. (Page 433.)

Methods of applying water.—About every method of irrigation practice can be found in some part of the United States. The irrigators of western America include nearly all nationalities, and each of these is inclined to follow the methods that he brought from his native country. The Chinese irrigate their truck-gardens after the Chinese fashion, and the same is true of Italians, Spanish and Mexicans. There are in all about thirty different methods of applying water in use in the United States. These fall, however, into three general classes: checks, flooding and furrows.

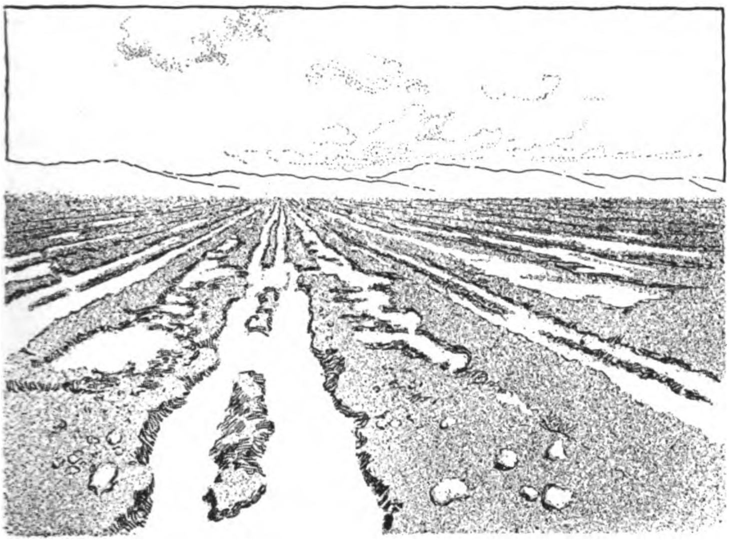


Fig. 594. The first irrigation by flooding.

The check system.—The check system was introduced by the Spaniards and is still followed in New Mexico. These checks are rather small—50 to 100 feet square—and divide the land into a series of basins by means of low ridges. The divisions that form the checks vary in shape with the differences in the contour of the country. When the slope is slight and uniform, these are usually rectangular. When the slopes are heavier and irregular, then the checks follow closely the contours. Figs. 592 and 593 are examples of contour and rectangular checking. The areas included in these checks range from one-fifth of an acre to fifty acres, the tendency at present being against both extremes, large checking leading to waste of water and to the washing of fields when the large volumes required are employed.

The flooding system.— In the Rocky mountain states, flooding is the prevailing method. The water is distributed over the field by small ditches that follow approximately the contours, having sufficient grade, however, to give the water a good velocity, and from these field ditches it is turned out at frequent intervals to run down the slope, being caused to spread over and cover the entire area by an irrigator working with a shovel. These field ditches run parallel to each other and are 60 to 200 feet apart, the practice today being toward having them closer together. In irrigating by this method, water is first turned into the upper laterals and the waste-water is caught up by the one below and distributed from that. (Fig. 594.) The field ditches are made by means of a single or double moldboard plow. (Fig. 595.) To turn water out of this, temporary earthen dams are made, or canvas dams (Fig. 596) are used.

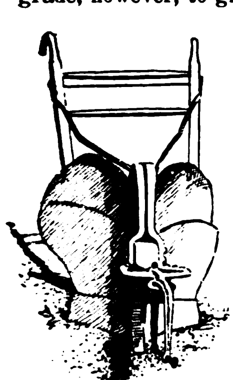


Fig. 595. Home-made lateral plow,—front view.

Furrow irrigation.— Furrows are used for the irrigation of all cultivated crops like potatoes, sugar-beets and corn (Figs. 597, 598). It is also used in some sections for the irrigation of timothy and alfalfa hay, and small grain. One form of furrow irrigation employed, originated in the Yakima valley of Washington, where flooding the surface causes the soil to bake (Fig. 599). In this, a head ditch to supply the water is run along the upper side of the field. This head ditch consists of a series of levels connected by successive drops, the system requiring the water to stand at a uniform depth in each one of these ditch sections. In the lower side of these level sections of the ditch, wooden tubes (Fig. 600) are set in the bank about 2 feet apart. Usually these tubes are made of lath, ½ inch thick, 2 inches wide and 3 feet long, four of them nailed together forming a tube, the opening into the ditch being closed by means of a lath or shingle. Furrows run down the slope from these spouts, the width and depth of these furrows varying with the character of the land. In land in which the water percolates readily, the furrows are 2 to 4 feet apart. In some cases, however, they must be 12 to 18 inches apart. In the narrower cases the furrows are mere marks, not over 3 inches deep; after a crop has been once established every alternate furrow is abandoned. Sometimes in the place of the wooden spouts running through the bank of an earthen ditch, wooden flumes are employed, and in a few instances cement ditches have been constructed. A modification of the Yakima furrow method is found in Nevada and Utah, where the furrows are somewhat wider and larger.

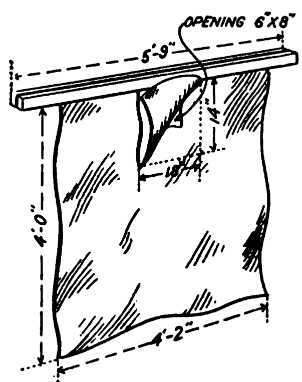


Fig. 596. Canvas dam with opening to divide an irrigating stream.

The cost of water and the great value of orchard products in California has led to great skill in the preparation of land for orchard irrigation, furrows, checks and basins, being the methods usually employed. For a number of years, much attention has been given to the relative merits of a considerable

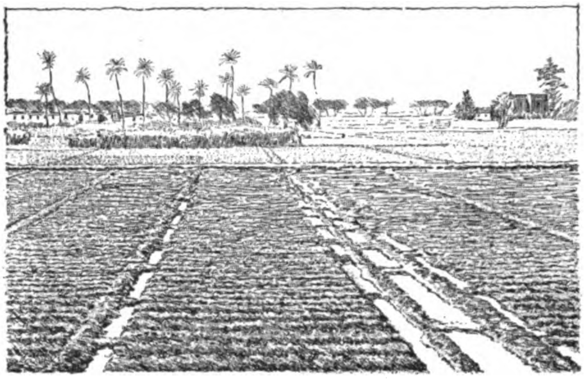


Fig. 597. Furrow irrigation for strawberries. Egypt.

number of shallow furrows between trees as against a small number of deep furrows. So far as loss from evaporation is concerned, the results favor a few deep furrows. Another method now but little used is that of basins. In the use of the basin method, provision is made for applying water in a basin around the trunk of each tree. Although economical of water, the results are less satisfactory than either the deep or shallow furrow methods.

Rice and marcite irrigation.—Rice and marcite irrigation (marcite is a mixture of clover and rye-grass) differ from ordinary irrigation methods in that the ground is kept continuously moist, if not continuously covered with water. As a rule, rice-fields are covered with water continuously to a depth of 2 to 6 inches, the only exception being when water is drawn off for the purpose of cultivation or harvesting. The preparation of a rice-field consists in grading the surface, the building of levees for holding the water to the required depth above the surface, and constructing drain ditches for its prompt and complete removal. The first irrigation of rice is known as the "sprout flow," in which the water is spread over the field to hasten germination and protect the seeds from the birds. This remains six to eight days. The next irrigation is the "stretch flow." The time of this depends largely on the weather. The "stretch flow" is for the purpose of hastening the upward growth of the rice plants and for smothering and killing weeds and grasses. In many countries, rice is sown broadcast and there is no cultivation, the "stretch flow" being practically continuous, and such weeds and grasses as are not smothered by the water have to be pulled out by hand. When the plants are drilled and cultivated, the "stretch flow" is followed by the "harvest flow," which remains until the grain is ripened. In Fig. 601 is shown the plan of the supply and drain ditches of a South Carolina rice plantation.

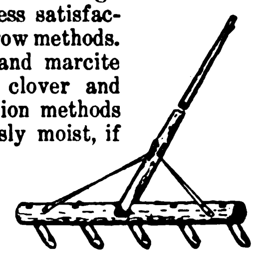


Fig. 598. Home-made marker for furrow irrigation.

The marcite fields of Italy and parts of Asia represent one of the most profitable forms of irrigation. Marcite irrigation is based on the use of warm water, the fields being prepared so as to permit of a continued flow of a thin sheet of warm water, the purpose of which is to keep the fields green and the grass growing, winter and summer. In hot weather, this thin sheet of water cools the soil; in cold weather, it warms it. In order to permit of this continuous use of water, there must be ample provision for drainage, and this is done by dividing a field into a series of gently sloping ridges. The supply ditches run on the summits of these ridges and the drain ditches in the hollows between. In Italy these ridges are 50 feet wide, each slope being about 25 feet. They are, as a rule, about 300 feet long, the top being level, so that when the supply ditch is filled, it will flow over the edge the entire length. The drain ditches between them have a drop of about 4 inches in 300 feet. This varies somewhat with the slope of the country. At the lower end of each series of ridges and drains there is another supply ditch, the waste-water from the first row of ridges escaping into the next supply ditch and serving to feed the succeeding row of ridges. Fig. 602 shows the supply and drain ditches on a farm near Vigentino. In arranging for the irrigation of marcite fields, about 35 cubic feet of water per second are provided for every fifty acres. Nearly all this water escapes and is used over and over again, the only loss being that which escapes below as seepage or upward as evaporation.

The duty of water.—The duty of water in irrigation is the area of land irrigated by a given volume of water. As water becomes more valuable, the increase of the duty becomes more and more important, and studies of methods of soil cultivation to conserve moisture, and thus raise the duty, have become an important feature of governmental aid in all irrigated countries. The two chief factors in increasing the duty of water are to lessen losses

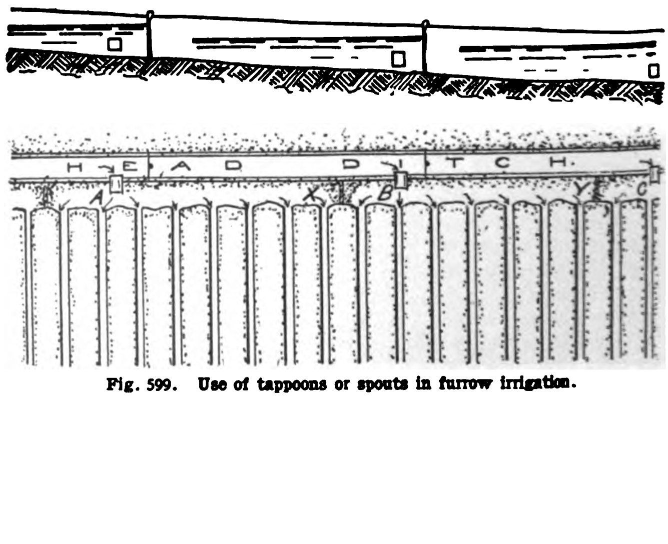


Fig. 599. Use of tappoons or spouts in furrow irrigation.

from seepage in canals and losses from evaporation from fields. In the latter, methods of applying water which will permit of the cultivation of the surface in the shortest possible time after irrigation, and thus prevent evaporation and cause the water to sink deeply into the soil so that roots will feed at a greater depth, are proving to be the factors of greatest importance.

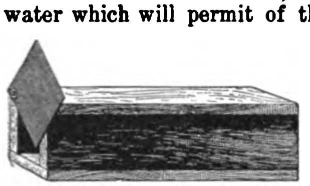


Fig. 600. Tube for diverting water to furrows.

In Italy the duty of water varies from 1 cubic foot per second for the irrigation of 26 acres of rice to 1 cubic foot per second for 160 acres of field crops. The irrigation of rice in the southern part of the United States requires a depth of about 2 feet of water in addition to the rainfall. In India the highest duty of water is secured when it is lifted from wells, 1 cubic foot per second irrigating as many as 250 acres. The following table shows the depths of water used in the irrigation of different crops and the length of the irrigation period in the United States, taken from measurements made by the Office of Experiment Stations of the United States Department of Agriculture in 1904:

Depth of Water Used for Different Crops and the Irrigating Season for Each.

Crop	Depth of irrigation	Irrigating season
	Feet	
Potatoes	3.94	May 17 to Sept. 15
Alfalfa	3.39	April 1 to Sept. 22
Orchard	2.76	April 15 to Sept. 2
Wheat	2.68	April 1 to July 26
Sugar-beets	2.15	July 13 to Aug. 17
Oats	1.73	May 22 to Aug. 20
Barley	1.49	June 12 to Aug. 1
Corn	1.40	July 24 to July 29

The cost of water.—There are two elements involved in fixing the cost of water in irrigation. One is the cost for the water itself. The other is the cost of its diversion and transportation to the place of use. In many European countries where streams are under public ownership, a charge is made for the water diverted from the stream. In Italy this rental for water helps to pay the state expenses of supervision. In India and Egypt it is often not separated from the other items of expense, because land and water are both owned by the state, and when private parties divert streams in India, a payment is required for the water used. In the United States, no charge is made for the water diverted. Appropriators of water to irrigate their own land, or water to fill great canals to irrigate the lands of others, each acquire the water free of any tax. When irrigators are part owners of canals in the United States and Canada, the only cost of water is the expense of maintaining and operating the canals. When water is taken from canals that are built to serve as carriers of water, the charges vary widely. These charges in the United States, however, are not burdensome; few canal companies have found the furnishing of water for an annual rental a remunerative undertaking.

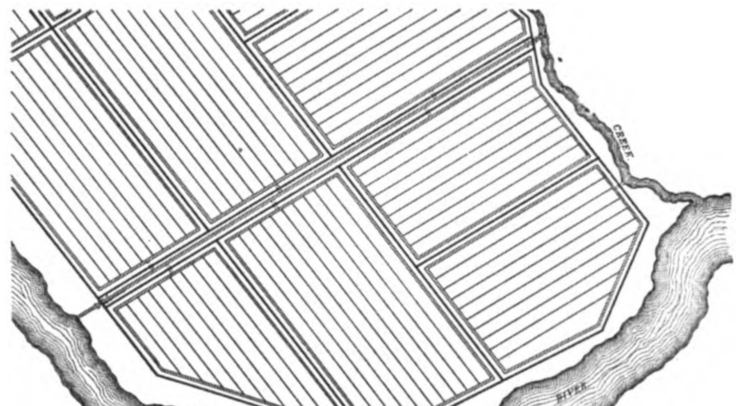


Fig. 601. Plan of rice plantation in the Carolinas.

A perplexing question connected with charges for water is as to whether they shall be uniform throughout a canal system, or whether, like railroad rates, the charge shall be based on the distance that the water is carried. On a canal 100 miles long, the expense of furnishing water at the lower end is far greater than at the upper end. It often happens that the volume of water which has to be turned in at the head to supply an inch at the lower end will supply 4 or 5 inches at the upper end. On some Italian canals, this cost of service and the great loss in carriage is taken into account, and the charges at the lower end are considerably greater than at the upper end ; but on all American canals charges are uniform throughout the length. In India and Egypt, practically all the water charges are based on the area irrigated.

The cost of water in the United States varies so widely in different sections that any attempt at averages would be misleading. On some canals the cost is as low as 15 or 20 cents an acre per year. From this it rises to as high as $15 an acre per year, or even higher in southern California in periods of exceptional drought.

The cost of pumping water in the Hawaiian islands sometimes reaches $35 an acre. In Italy, the annual charges from some of the larger canals vary from $120 to $180 for a cubic foot of water per second, or about $1 per acre. In India the charge is 80 cents to $1.15 an acre per year; in Egypt, about $3.75 an acre per year. In Victoria, Australia, it varies from 50 cents to $4.50 an acre-foot, per year.

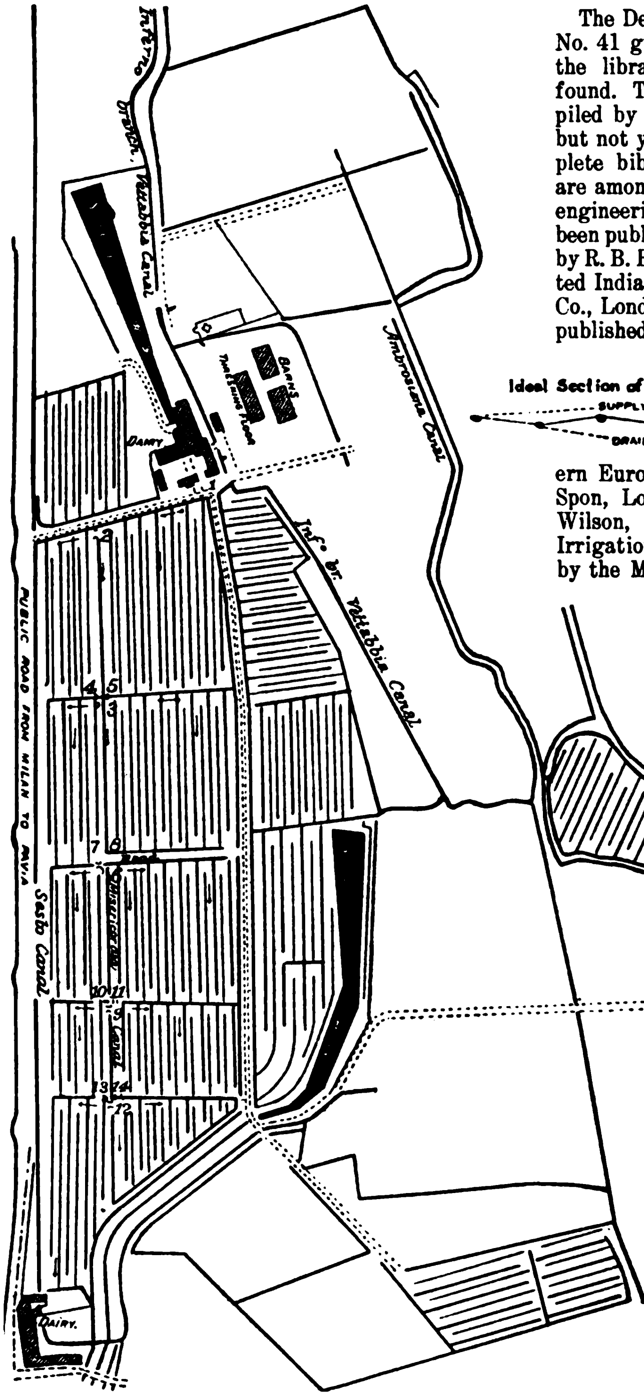


Fig. 602. Farm near Vigentino, Italy, showing location of irrigating ditches and two springs and arrangement of marcite fields.

Literature.

The Department of Agriculture Library Bulletin No. 41 gives a list of irrigation publications, with the libraries in Washington where they can be found. This has been supplemented by a list compiled by the American Society of Civil Engineers, but not yet published. The two make a fairly complete bibliography of the subject. The following are among the most important works on irrigation engineering and irrigation practice which have been published privately: Irrigation Works of India, by R. B. Buckley, published by Spon, London; Irrigated India, by A. Deakin, published by W. Thacker & Co., London; Egyptian Irrigation, by W. Willcocks, published by Spon, London; Italian Irrigation, by R. B. Smith, published by Blackwood & Sons, Edinburgh, Scotland; Irrigation in Southern Europe, by C. C. Scott-Moncrieff, published by Spon, London; Irrigation Engineering, by H. M. Wilson, published by Wiley & Co., New York; Irrigation and Drainage, by F. H. King, published by the Macmillan Company, New York; Irrigation Institutions, by Elwood Mead, published by the Macmillan Company, New York; Irrigation in the United States, by F. H. Newell, published by Crowell & Co., New York; Irrigation for Farm and Garden, by H. Stewart, published by Orange Judd Company, New York; Irrigation Farming, by L. Wilcox, published by Orange Judd Company, New York; Primer of Irrigation, by D. H. Anderson, published by "Irrigation Age," Chicago. The most important sources of information on this subject both in America and other countries are, however, government reports. The publications of the United States government include reports by the Departments of Agriculture and the Interior. The reports of the Department of Agriculture are published as bulletins of the Office of Experiment Stations. The reports of the Department of the Interior are published by the Geological Survey, the Reclamation Service and the Census Bureau. In addition to the above, the states having state engineers publish reports of the work of these officers. This includes the states of Colorado, Wyoming, Nebraska, Idaho, Utah, Nevada, Montana, South Dakota and North Dakota.

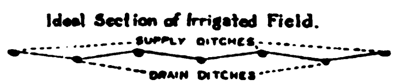


Plate XXII. An irrigation dam. Modesto, California

IRRIGATION IN HUMID REGIONS

By *R. P. Teele*

In arid regions irrigation is a necessity if agriculture is to exist, and the only questions relate to methods of securing water and of applying it. In humid regions, however, agriculture is being practiced successfully without irrigation, and it becomes not a necessity, but a means of insurance against drought, or of increasing production, similar to the use of fertilizers, crop rotation, or practicing cultivation. It belongs, therefore, to an advanced state of agriculture, where new land convenient to markets is no longer available and increased demands for agricultural products must be met by securing larger returns from land already in use, rather than by bringing larger areas into cultivation. For this reason irrigation is practiced but little in the humid sections of the United States; but it may be expected to become more general in the future. On the other hand, in the thickly settled countries of Europe irrigation has been practiced for centuries in regions where the rainfall is as great as that in the eastern half of the United States, and where irrigated fields are interspersed with those that depend on rainfall alone.

The occasion for irrigation arises, not from a deficiency in the total amount of rainfall, but from its uneven distribution, making alternating periods of abundance and scarcity. The frequency of periods of drought of greater or less duration is well illustrated by the rainfall record of Philadelphia, which may be considered typical of the humid region. This record is taken because of the length of the period covered,—1825 to 1895. During the seventy years covered, the rainfall was at least one inch below the normal in some month of the growing season in 88 per cent of the years; dry periods of two months occurred in 56 per cent of the years; and shortages covering three months occurred in 30 per cent of the years. The frequency with which different crops will suffer depends on their ability to survive periods of drought. According to the record, crops having short growing periods will be injured in at least 88 per cent of the seasons; annual crops generally will be below the normal in about half the years; while all crops will receive too little water in about one-third of the seasons. It follows that irrigation is of greatest value for those crops that suffer most from short periods of drought, that is, for garden truck, the growing season of which covers but a few weeks; and small-fruits, which dry up and become worthless if a drought occurs at the time of ripening. It is of great value for meadows also, since the growth of grass depends on a continuous supply of water.

Irrigation of meadows.

In European countries the irrigation of meadows has been practiced for centuries. This is true of Great Britain, Holland, Germany, Switzerland, Italy and France. Water is kept running over the meadows almost continuously, especially in winter, when it prevents the freezing of the ground and keeps the grass growing. In Italy marcite, a mixture of clover and Italian rye-grass, is grown in this way, and yields of 10 to 15 tons per acre to each cutting, and 8 to 12 cuttings per year, are reported. In the other countries mentioned, the meadow lands susceptible of irrigation are considered among the most valuable lands.

In the United States the irrigation of meadows in the manner just described is not practiced, but there seems to be no reason why it should not be where the large quantities of water required can be secured easily, and especially where sewage water is available. The use of sewage water in this way would be of great benefit to agriculture, would produce no unhealthful conditions where it is used, and would prevent the pollution of streams by discharging the sewage water into them, which is a growing evil.

Fig. 603. **Wheatfield at Cheyenne, Wyoming, irrigated by a windmill supply.** To illustrate irrigation in semi-arid regions by utilizing small water-supplies, a type of individual reclamation that is now receiving much attention. Some of these supplies are so small as to have been considered of no value hitherto.

The irrigation of meadows at times during the summer, however, is practiced to a certain extent in the humid parts of the United States. Reports from four counties in Pennsylvania,—Lancaster, Berks, Lehigh, Northampton — show about 800 acres of irrigated meadow, the yield from which is about double that from similar meadows not irrigated. With few exceptions, these meadows are on low land to which water from streams can be applied easily by gravity. The stream is tapped above the meadow and the water carried in a ditch having less grade than the stream, which will bring the water higher than the land to be irrigated. Ditches are run through the land, and the water turned out from these through cuts in the banks and allowed to spread over the ground. In order that the land may be wet uniformly, it is necessary that the land be smooth and nearly level. Fig. 604 illustrates the method of flooding meadow land. AB is the main supply ditch, while CD and EF are smaller ditches running through the meadow. The supply ditch is dammed at A until enough water has entered CD to wet thoroughly the land down as far as EF, when the dam at A is removed, the head of CD is dammed, and the water flows down to the dam at B, which turns the water into EF, from which it flows out on the land below that ditch. The usual custom is to allow the water to run on a field continuously for three or four days, then shut it off for periods varying from three or four days to a month. When a meadow is used for pasture, the best practice is to divide it, and irrigate one part while the other is being pastured. There is little expense to this kind of irrigation. There are a great many places where small streams flowing through meadows can be put to use by the construction of small dams and ditches which require almost no cash outlay and only a little labor.

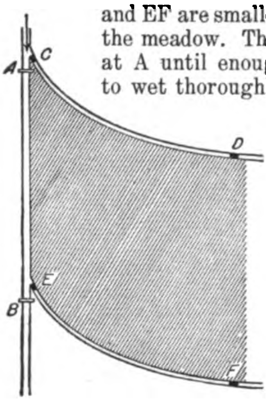


Fig. 604. Flooding from field laterals.

Irrigation of small-fruits.

Small-fruits, as berries and currants, do not require large quantities of water, but the lack of water at the time of ripening causes small and seedy fruit, reducing both the yield and the quality. In years when such droughts do not occur there will be little benefit from irrigation, but when they do occur the benefits will be great. Experiments made by the New Jersey Experiment Station covering three years showed a very large gain from irrigation in one year and no gains in the other two years. The same is found to be true by persons raising small-fruits on a commercial basis. The profits in the dry years are more than sufficient to pay the fixed charges for the years when the equipment is not in use, as well as the expenses in years when irrigation is necessary.

Irrigation of truck gardens.

Truck gardens show the greatest profit due to irrigation, and a large number of gardeners in the vicinities of large cities practice it. Few of these persons keep records of cost and profits, but all agree to the great value of irrigation. In ordinary years it increases the yields, and in dry years it means a full crop instead of no crop, the returns in a single dry year often being equal to the first cost of providing a water-supply.

Irrigation of field crops.

Field crops are not generally irrigated, but experiments conducted by Professor King at the Wisconsin Agricultural Experiment Station go to show that it would be profitable in many cases. Compared with average yields for the state, the average increase in the yield of clover hay on irrigated land over that from unirrigated land was 2½ tons per acre; the average increase in yield of corn was 26.95 bushels per acre, and potatoes showed an increase of 83.9 bushels per acre. The annual cost of irrigation at Madison, Wis., was $6.68 per acre, not including interest on the first cost of equipment, but including all extra labor. At current prices this leaves a net profit of about $20 per acre on hay, $11 per acre on corn, and $14 per acre on potatoes. It should be noted that the returns are compared with the averages for the state, which is hardly fair, as irrigation will be practiced only by the industrious, careful farmer, and the returns should be compared with those received without irrigation by equally good farmers. Data for this are not available; but it is believed that where water can be secured cheaply irrigation of farm crops will prove profitable.

Methods of applying water.

Throughout the humid part of the United States there are in general use two methods of applying water to fruit and garden crops—in furrows and by sprinkling. The sixty plants or establishments reported in a bulletin of the United States Department of Agriculture issued in 1906 are about equally divided between the two.

The furrow system.—The furrow system has the great advantage in cheapness and simplicity, and for this reason is preferable where it can be used, but it is not adapted to all kinds of land. The crops irrigated are, for the most part, shallow-rooting, and in light sandy soils water run in furrows soon sinks out of reach of plant-roots and is lost to them. Therefore, the system is best adapted to comparatively heavy soils. Water is brought to the highest side of the tract to be watered and from there run in furrows between the rows of plants. The furrows must have only a light slope away from the ditch, or the water will run through rapidy without soaking into the soil, and waste at the lower end. If the land is nearly level, the supply ditch or pipe may be run along the highest

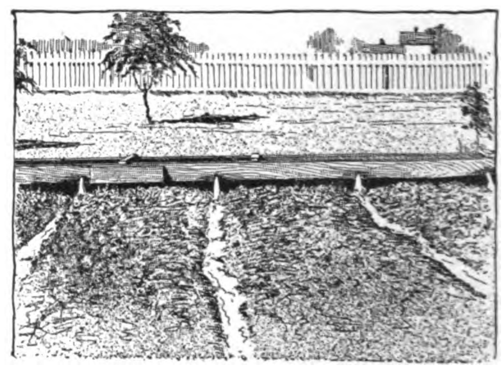


Fig. 605. Wooden head-flume.

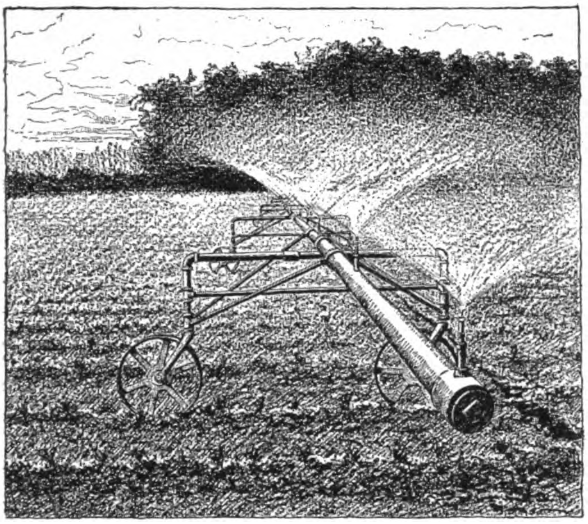


Fig. 606. A movable sprinkler used by David Astle, Vineland, N. J., in truck-garden.

side of the field, and the furrows run straight down the slope. If the slope is great or the land is rolling, the furrows should run across the slope, or around the hills in such directions as will give the proper slope. When fields are to be irrigated in this way, the rows of plants should be laid out with this in view.

Water may be brought to the heads of the furrows in an open ditch, from which it is turned out through cuts in the banks at short intervals and is directed into the furrows. It may be brought in a wooden flume which is provided with holes opposite the furrows (Fig. 605), the flow from which is controlled by sheet-iron gates; in a metal pipe which is provided with outlets at the furrows or at greater distances, the water being run into the furrows through hose connected to the pipe outlets; or, in home-made canvas hose having outlets at the furrows. Fig. 597 shows a strawberry field being irrigated by the furrow method. Furrow irrigation in the arid West is shown in Fig. 90. The chief advantages of the furrow method are: No special skill is required to lay it out; one man can handle a large stream of water; the water need not be raised any higher than the land to be irrigated, making a great saving in power when water is pumped; and water can be supplied at any time without danger of scalding the plants, as the water does not touch them.

Sprinkling. — Sprinkling is especially adapted to light soils and shallow-rooting crops, because the water is applied at the surface and can be applied in such small quantities that it will not sink beyond the reach of plants. Frequent light irrigations are the rule in sprinkling, thus avoiding the danger of swamping the plants if a heavy rainfall follows directly after irrigation. It is more expensive than furrow irrigation because of the large expense for pipe and hose, the increased power required to overcome friction in the pipes and to supply pressure for the sprinklers. In many instances the power required is more than three times as much as is necessary to raise the water to the height of the land. For sprinkling, the water must be brought to the land under pressure and, therefore, iron pipe is used. The pipes may be buried, with standpipes at proper intervals for hose connections, when they will not interfere with cultivation; but they are often laid on top of the ground and are removed when the land is cultivated. The most common practice seems to be to lay the main supply pipes under ground and use some kind of movable pipes or hose in the fields. Figs. 606 and 607 show two such outfits. In both cases the main supply pipe is at the side of the field, and is provided with standpipes at intervals. Fig. 606 shows a pipe with sprinklers supported on wheels, the pipe being connected by hose to the standpipes on the supply pipe. The sprinkler can be pushed along to the limit of the hose, when it is disconnected and attached to the next standpipe. The sprinklers shown in Fig. 607 are used in the same way, except that the pipe is picked up and moved when one section has received sufficient water.

A permanent system of overhead pipes, high enough to allow cultivation below, is sometimes used. The water is discharged from the pipes through holes which are in line, or from small brass plugs inserted in the pipes. The pipes are turned so as to discharge the water at different angles, throwing water 25 feet on each side of the pipe line.

Ordinary waterwitches or revolving sprinklers such as are used commonly on lawns are much employed, and many persons sprinkle from hand hose with or without nozzles. This last is the cheapest to install, but more expensive to operate, since each nozzle requires the full time of one man. The

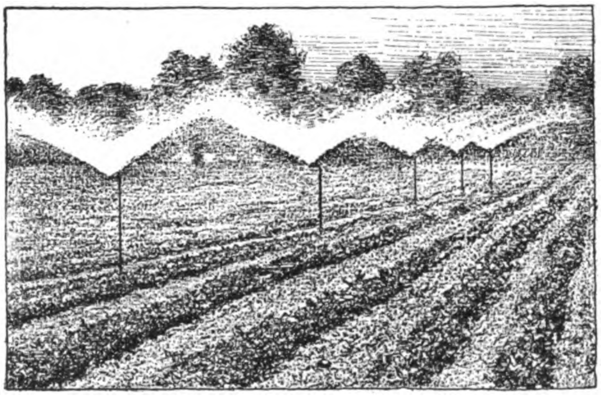


Fig. 607. System of irrigation for a truck-farm in which the pipe is lifted and carried from one section to another.

perforated-pipe systems have higher first cost, but require little attention when in use.

Cole's trench system.

A system of irrigation and drainage combined, adapted to steep hillsides, was devised by Asahel N. Cole, of Wellsville, N. Y., and patented July 22, 1884. The system is illustrated in Fig. 608. It consists essentially of a series of ditches, 3 to 5 feet wide and of about the same depth, placed one below the other, a rod or more apart. Each ditch is designed to be a reservoir, below frost line, which will carry off the surplus water or store

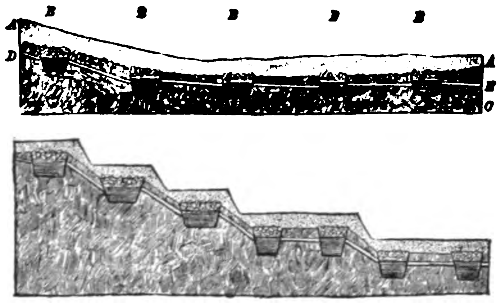


Fig. 608. Diagrams of Cole's "New System" of handling soil water. AA, surface soil; B, trenches; C, subsoil; D, overflow trenches; E, outlet or drainage trench. From Cole's "New Agriculture," published by the late Wm. C. Harris.

it until drawn on by the growing crops. Cobblestones to the depth of a foot or two are put loosely in the bottom of the trench, covered with flat stones, over which is placed a quantity of smaller stones. This is covered with weeds, brush, cornstalks, or any other available material, to prevent the fine earth filling the open spaces. Manure might be put above this, and then the surface soil replaced. The trenches are all connected by overflow drains. The system never became popular, but shows what may be done on hilly land. The results secured by Mr. Cole were marked.

Cost of irrigation.

Equipment varies so widely that general statements as to cost are of little value. Below are given the costs of a few typical irrigation plants, as published in reports of the United States Department of Agriculture:

In Northampton county, Pa., 3½ acres are irrigated with a No. 6 ram. The ram is fed through 160 feet of 2½-inch pipe, with a head of 20 feet, and discharges through 2,000 feet of 1¼-inch pipe, into a boiler-iron tank 4½ by 8 by 7 feet, 185 feet above the ram. The water is distributed by hand sprinkling and by a 4-arm revolving sprinkler, which is moved about once an hour. The distribution requires 1,500 feet of 1¼-inch pipe, and several lengths of ¾-inch and 1-inch hose. The total cost of the plant was $850, or $252.90 per acre. Assuming interest, taxes and depreciation to equal 20 per cent, the annual fixed charges on the plant are $48.60. The average cost of applying water with hand sprinklers is reported to be $1.80 per acre. With rams there is no fuel cost, and the total annual cost is therefore $50.40 per acre.

In the same county another tract of 4 acres is irrigated with a No. 8 ram. The ram is fed by 75 feet of 3½-inch pipe, with a head of 11 feet, and raises the water 80 feet through 575 feet of 1¼-inch pipe, discharging into a cistern 8 by 8 by 8 feet. Water is distributed through 1,000 feet of 1¼-inch and 1-inch pipe, with T's for outlets every 40 feet. The water is applied by sprinkling partly by hand and partly by a waterwitch. One hundred feet of 1-inch hose is used, half of which is replaced each year. The cost of the plant was $180, or $45 per acre. Estimating fixed charges as before gives an annual cost of $9 per acre, and adding $1.80 for applying the water gives a total annual cost of $10.80 per acre.

In Middlesex county, N. J., 2 acres of truck are irrigated with city water from New Brunswick, at $1 per 1,000 cubic feet. The water is applied in furrows, to which it is carried by hose. The total cost of hose and pipe was $25, or $12.50 per acre, making annual fixed charges $2.50 per acre. The average cost of applying water in this way is 75 cents per acre, and the charges for water vary with the seasons, in 1905 being $12.50 per acre. This makes the total annual cost $15.75 per acre.

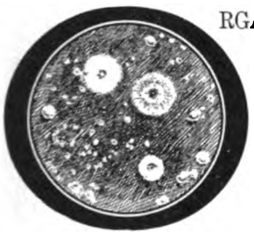
Seven acres of truck in Queens county, N. Y., are irrigated with a plant costing $1,200, or $171 per acre. There are five 2-inch driven wells 20 feet deep, costing $28 each. The water stands at 10 feet below the surface. A vertical boiler supplies steam to a duplex pump delivering 80 gallons per minute against a vertical lift of 67 feet, through 1,200 feet of 2-inch pipe, into a wooden reservoir holding 10,000 gallons. A 12-foot windmill furnishes an additional supply. The water is distributed through a 2-inch main with 1¼-inch branches 150 feet apart. These branches have 1-inch outlets 75 feet apart, to which waterwitch lines are connected by hose. The waterwitch lines consist of 1-inch pipe with ⅜-inch risers every 12 feet, on which there are sprinklers. About 50 feet of hose is used in connecting these to the standpipes. Three thousand feet of 2-inch pipe is used. Fixed charges at 20 per cent amount to $34.20 per acre, applying water costs about $2 per acre, and fuel costs about $1 per 10-hour day, and the area watered in this time is one acre. The number of irrigations varies with the seasons. Assuming it to be five, it gives a fuel cost of $5 per acre. This gives a total annual cost of $41.20 per acre.

Literature.

The literature on the subject of irrigation in humid parts of the United States consists chiefly of reports issued by the United States Department of Agriculture, that department having issued a number of bulletins describing plants now in use and giving the results of experiments at the State experiment stations. Among other works treating this subject may be mentioned: New Agriculture, or The Waters Led Captive, by Asahel N. Cole, New York, 1885; and Irrigation and Drainage, by F. H. King, New York, 1889.

CHAPTER XIII

TREATMENT OF THE SOIL WITH REFERENCE TO ORGANISMS



ORGANISMS OF VARIOUS KINDS inhabit the soil and have much to do with the growth of plants therein. They are active agents in chemical changes. Sometimes these organisms are symbiotic; that is, they have a vital connection or relationship with other plants, each plant profiting thereby, as in the case of the organisms that inhabit the tubercles of various roots. Others work directly, or non-symbiotically. It is important that the reader appreciate the fact that the relation of germs to the appropriation of free nitrogen, for example, may be non-symbiotic, when certain germs appropriate it directly from the air on their own account, or symbiotic, when other kinds of germs work in conjunction with leguminous plants.

As commonly used, the term "germ life" refers to a series of microscopic plants found in great abundance in all soil and waters, and indeed nearly everywhere on the surface of the earth. That the soil is filled with organic material in the form of roots of plants, bodies of animals, and the like is, of course, perfectly evident; but that it is teeming with inconceivable numbers of invisible organisms, which find the soil their natural habitat and produce constant and profound changes in its nature, has only recently been learned. Still more recently have we come to realize that the numerous and varied activities of these soil organisms determine soil fertility; that without them the soil would probably never have supported vegetation, and that it would certainly soon become unfit for higher plants if their activities should cease. The continued cultivation of the soil, century after century, would have been impossible without the aid of these invisible organisms.

Kinds of soil organisms.

The organisms commonly included under the term germ life are of many kinds. Botanically they represent several types of low or flowerless plants. All of these organisms are colorless plants, and hence are considered by most authorities to belong to the highly important group of fungi. Of the fungi there are three types whose activities are of importance in the soil.

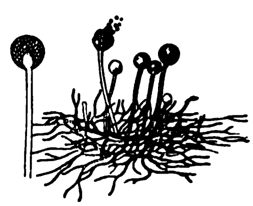


Fig. 609. One of the larger fungi. Common mold, or mucor. The fibrous part is the mycelium. Fruiting bodies rise from it.

(1) *The higher fungi.*—This group includes plants commonly called molds, mushrooms, toadstools, and the like. These form a large group of widely different plants. They are frequently large and are not commonly included under the term germ life, since, as generally understood, this term refers to invisible organisms. But their activities are so closely related to those of the smaller soil organisms that they must be grouped with them in their relations to the soil. The body of these plants, in most cases, consists of a mass of minute threads, which penetrate more or less deeply the substance on which the plant is found. Fig. 609. Some of the larger forms, as mushrooms, produce an expanded top on the under side of which the fruiting bodies or spores are borne.

The higher fungi differ from the bacteria in structure, form and size, being larger and more complex. In general they consist of a branching thread-like body, the mycelium, and reproductive bodies, the spores. The mycelium, spores and mode of formation of spores are subject to great variation in the different species. The spore in all cases is the organ of multiplication or hibernation, which, when conditions are suitable, germinates and gives rise directly or indirectly to the mycelium, which is the vegetative body of the fungus. This mycelium may grow extensively through suitable substrata—soil, manure, wood, host-plants—producing poisons or solvents, as do the bacteria. A passage is thus made through cell-walls, bringing disease and possibly death, if the host be a living plant. The mycelium eventually produces spores in enormous numbers, which serve to disseminate, multiply and perpetuate the disease. Many fungi produce two or more kinds of spores—one kind that serves the purpose of immediate multiplication and dissemination, another kind of greater resistance that withstands adverse conditions, as cold, heat, drought and exhaustion of food supply. The kinds of fungi are very numerous and diverse.

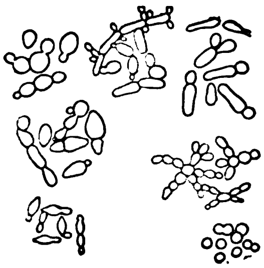


Fig. 610. Various kinds of yeast.

(2) *Yeasts.*—These are wholly microscopic plants, oval or spherical in shape, and multiply by budding. They are moderately abundant in the soil, especially at the surface. (Fig. 610.)

(3) *Bacteria.*—These are still more minute organisms, constituting the smallest known living things. They are very simple in form, being either minute spheres, rods or spirals. They differ from yeasts chiefly in the fact that they multiply by simple division instead of by budding. (Figs. 611–617.)

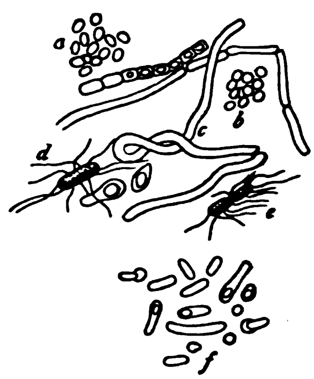


Fig. 612. Various soil bacteria. *a*, nitrate organism; *b*, nitrite organism; *c*, *Bacterium graveolens*; *d*, *B. fusiformis*; *e*, *B. subtilis*; *f*, *Closteridium Pasteurianum*. All highly magnified.

Each of these organisms plays a part in the transformation of the soil. While to some extent the activities of the three are similar, still, in general, the different groups are concerned in quite different functions.

Bacteria chiefly concern us at this time. The smallest of them are about $\frac{1}{150000}$ of an inch long by $\frac{1}{450000}$ of an inch wide, while a very few exceptionally large ones are about $\frac{1}{200}$ of an inch long by $\frac{1}{4000}$ wide. Most of the common species fall between the limits of $\frac{1}{25000}$ and $\frac{1}{2500}$ of an inch in length. Notwithstanding the extreme minuteness of these organisms they are of vast import, some species causing diseases of man, of domestic animals, or of cultivated plants, while others bring about important changes in the dairy, in the soil, and in the manure-pile. Their ability to bring about these important changes rests chiefly on two factors: (1) the extreme rapidity with which they can multiply; (2) the production of various chemical compounds of important poisonous or solvent action. Multiplication is accomplished by one organism dividing directly into two, an operation which under favorable conditions requires only fifteen to thirty minutes and may be repeated continuously. This constant doubling every quarter or half hour would lead to the production of enormous numbers of organisms from a single parent in the course of a day, if unchecked. It is this rapid increase under favorable environment, as in a suitable host-plant or animal or a bit of decaying material, that compensates their smallness and their shortness of life. These minute vegetable organisms are usually parasitic on other plants or on animals, or saprophytic on the decaying substances of plants or animals.

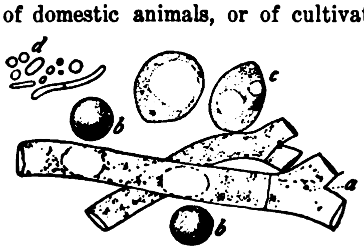


Fig. 611. To show relative sizes of molds (*a*), yeast (*b* and *c*), and bacteria (*d*).

Certain bacteria have the power to produce extremely powerful poisons, resulting in disease in susceptible animals. Other bacteria are able to excrete compounds which can dissolve cellulose or substances of the plant-cell and thus bring about disease or decay.

GERM LIFE IN THE SOIL

By *H. W. Conn*

Microscopic plants are universally distributed in all soils where the conditions are favorable to them, but their abundance and importance in any soil depend on many factors. The numbers that are found in the soil vary so widely that few general statements can be made. Since they are all fungi, they agree in their general conditions of life. They require no sunlight, but most of them do require an abundance of organic food. On pure and simple minerals they are commonly unable to subsist at all, although some of them, and these are important in soil transformations, can utilize the simple compounds of the soil, like carbonates and sulfates, which are commonly classed with mineral rather than organic substances. They are all quite dependent on a good supply of water. Bacteria and yeasts cannot grow unless there be 25 to 30 per cent of water in the medium on which they live. The molds, however, do not need so much moisture and grow in places in which bacteria and yeasts would fail to develop.

From these general conditions of life the distribution of germ life may be readily understood. In dry, sandy soil all types of organisms are practically absent, since they have no food supply. They are therefore not to be found in appreciable quantity in desert soils. In moist soils they are always found, and their abundance is proportional to the amount and kind of organic matter in the soil. When the amount of vegetable matter in and on the soil, such as wood, leaves, cellulose and the like, is abundant, the higher fungi, the molds and mushrooms are abundant. Thus, in the forests, the soil, for some inches in depth, is filled with an interlacing mass of the threads, or mycelium, of many varieties of these plants, which permeate it in all directions. Whenever the soil contains considerable quantities of sugar, the yeast fungi will be scattered in great abundance through the superficial layers.

When the quantity of proteid material is large the bacteria abound. Proteid matter is found wherever any animal or vegetable substance accumulates. Animal remains and animal secretions are particularly rich in proteid and, hence, wherever such substances are found, bacteria accumulate in great numbers. Around barnyards and in manure heaps, at any place where sewage leaches into the soil, around the decaying carcasses of animals, bacteria may be found in inconceivable numbers. In such places they have been found in numbers as high as 100,000,000 per gram of soil. Even in ordinary loam the bacteria are very abundant, 5,000,000 per gram having been found in common garden soil.

These microscopic organisms are found chiefly in the superficial layers of the soil and never at any great depths. The bulk of them are in the first six inches. Below this they decrease rapidly, and at depths of six feet they are very few or absolutely wanting. In some places, however, they may be found at greater depths, being carried downward by the percolating streams of water. At great depths they are never found. The reason for this superficial distribution is readily understood when we remember that their food is derived from the surface of the ground, and also that, as a rule, they require oxygen, which gas is abundant near the surface, but does not readily penetrate to any considerable depth.

The cycle of life.

Primarily these organisms are, of course, simply filling the ordinary functions of life, growth and reproduction, but incidentally their activities form one of the links in nature's grand adjustments. To comprehend this we must understand how it is that the life of the world continues indefinitely without exhaustion. Both plants and animals require food, and much of this food is limited in quantity. Of plant-foods the soil contains only a moderate amount at any time, and yet for unknown millions of years both plants and animals have been consuming food; nor is there any reason for thinking this food is less abundant today than in ages past. The explanation of this phenomenon is that nature's laws are such that the same material is used over and over again. One group of organisms consuming the material fits it for food for the second group, and the second group, likewise consuming it for its own purposes, fits it for a third group, and the third group brings it back again into a condition to be used once more by the first group. Thus the food ingredients are passing around in endless cycles, and as long as the circulation can be kept up there need be no exhaustion of the supply.

One of the essential links in this cycle is supplied by the germ life in the soil. Agriculture is, of course, dependent on the continued growth of green plants, for all agricultural products can be traced to the vegetation on the soil. All soil manipulation has as its aim the stimulation of the growth of green plants. Such plants are at work constantly, building compounds of greater or less complexity out of soil ingredients. The compounds thus made are commonly called organic compounds, and when once built up into such materials the elements of which they are composed are no longer in condition to be used by plants as food. They are too complex. Such complex compounds, however, do constitute the food of animals. Used now by animals these bodies are, in part, built up into even more complex bodies and are, in part, more or less broken down into simpler bodies again. But even though thus broken down, most of the fragments are not reduced to a condition in which the green vegetation can use them, for such vegetation requires its food in the form of simple chemical compounds of less complexity than most of the secreted products of animals or plants.

It is the function of the soil organisms to complete this reduction of compounds so as to bring them once more within the reach of the green plants, thus completing the cycle. Each of the above-mentioned groups of soil organisms has its own functions in this work. The higher fungi are chiefly concerned in breaking down the woody tissues of vegetable growth. The yeasts act on the sugars and also on the starches after they have been changed into sugar by enzymes (or ferments). The bacteria act on almost all kinds of organic materials, but primarily on proteids. By the combined action of the three, all kinds of organic products are broken down into simple ingredients and thus pushed around one step in nature's food cycle. Without their aid the soil would soon become clogged with the dead bodies of plants and animals as well as with their excretions, and would rapidly become unfit to support vegetation; and all life on the globe would cease.

The function of the soil organisms does not stop here. While green plants cannot feed on complex organic compounds, neither can they feed on simple elements nor on some of the simplest compounds. In this general destruction of organic bodies which is taking place in the soil, a considerable part of the material is reduced to forms too simple to be used by plants as food. Some parts are reduced to the simple chemical elements (as nitrogen, sulfur, hydrogen), while others reach such a simple condition of chemical combination (H_2S, CH_4, etc.) as to be still outside the reach of green vegetation. Here come into play certain of the soil organisms that are able to utilize these simple substances as part of their food. In doing so they cause the simple bodies to combine into more complex ones and, in the end, to assume a form in which they can once more be utilized by green vegetation, and thus start again in their journey around the cycle. Some of the soil bacteria even seize the free chemical elements.

Our knowledge of the functions of germ life in the soil is still very incomplete. The subject is new, scarcely thirty years having elapsed since the first bits of information were obtained. We already know enough to demonstrate that the continuation of life is dependent on them. They are aids in the breaking up of rocks into grains which constitute the soil; they are concerned in the production of available phosphorus and potassium salts from the rocks; they are intimately concerned in the production of the proper compounds of sulfur and iron for plant-life; they are constantly acting as scavengers, consuming, and thus destroying, the accumulation of offensive products which would otherwise clog the soil, and thus they are the agents which bring about the so-called "self-purification of the soil." They are also ever building up simple substances into more complex ones, thus making them into plant-foods. In all these as well as other respects they are indispensable allies to agriculture. Although invisible, and to most farmers unknown, they are ever at work.

Bacteria in relation to soil fertility.

The most important of the various soil organisms are bacteria, and these are most closely related to fertility. Apart from the question of moisture, the fertility of any soil depends on the presence of an abundance of easily assimilable plant-food, and this is chiefly dependent on the amount of organic material. Soil with plenty of organic matter will yield good crops, but without organic matter, even though minerals are supplied in quantity, the soil will yield little. The organic matter is largely in that part of the soil called the humus, and it has been long recognized that the richness of a soil is usually proportional to its quantity of humus.

Humus is a complex substance, especially abundant in rich loam, whose nature and origin is as yet only partly understood. In large degree, at all events, it comes from the decomposed bodies of animals and plants, and is produced chiefly, if not wholly, through the agency of soil organisms. It contains many different substances, including compounds of phosphorus, potassium, sulfur, iron and others, all of which are usually classed with minerals. But, in addition, it contains as its most important ingredient, from the fertility standpoint, nitrates or other bodies capable of easy conversion into nitrates. While bacteria do not, of course, supply the food ingredients to the soil, they are intimately concerned in the conversion of these ingredients into plant-food. We may best consider this relation under the heads of (1) nitrogen compounds and (2) other soil ingredients.

Nitrogen compounds and bacteria.

All green vegetation uses nitrogen, and there is good reason for believing that the nitrogen plant-food is largely assimilated in the form of nitrates. Thus nitrates are necessary to the production of soil fertility. For the production of nitrates in the soil, bacteria are absolutely necessary, and their action is therefore indispensable to vegetation.

The origin of these nitrates is twofold: (1) The decomposition of organic materials in the soil, (2) atmospheric nitrogen.

(1) *Decomposition of organic matter.*—The soil in all fertile regions is full of organic substances, a considerable part of which contain nitrogen. These are chiefly from three sources. (*a*) Vegetable remains, such as roots, fallen branches and leaves, and the fruits, nuts, and the like, of all kinds of plants. (*b*) The secretions of animals, the most prominent of which is urea and its allies. This material (contained in urine) is the condition in which practically all of the nitrogen leaves the bodies of animals, and, since all animals, great and small, secrete it and most of it enters the soil, the total amount of soil nitrogen from this source is very great. (*c*) The dead bodies of animals. With the exception of the few animals whose bodies fall into the streams, practically all others lie within or on the soil, and the total amount of such material is very large.

Such organic substances, although the foundation of soil fertility, are in no condition to be utilized until after they have undergone a series of chemical transformations. They must first be pulled to pieces. This process of pulling to pieces we commonly call decomposition, rotting, putrefaction or decay. The agents that produce the ordinary decomposition are wholly living, no purely chemical forces being able to accomplish it. Molds, yeasts and bacteria are all concerned, but in the decomposition of the nitrogenous material, bacteria are the chief agents. There are many species of soil bacteria engaged in the production of decay and putrefaction, and they bring about a variety of chemical changes, but there is a considerable similarity in the final results in all cases. The organic compounds are pulled to pieces and the fragments largely dissipated in the air. A variety of gases is produced containing the hydrogen, sulfur, carbon and oxygen. The carbon and part of the oxygen join the store of CO_2 (carbon dioxid) in the air. The sulfur, as explained later, is in part seized by sulfur bacteria and converted into sulfates. The nitrogen assumes different forms. A large part of it is reduced to ammonia gas (NH_3), which also tends to fly off into the air, as is indicated by the smell of ammonia commonly noticeable in the vicinity of a manure heap. Ammonia gas, however, is an active agent and readily combines with any acids that may be present, forming carbonates, sulfates or some other ammonium salts, and these, being solids instead of gases, remain fixed in the soil. Another part of the nitrogen is freed wholly from its combinations and becomes free nitrogen. This, being an inert gas, does not combine with anything, but flies off into the atmosphere and thus out of the reach of plants. So, by the agency of decomposition bacteria, the nitrogen is wholly freed from its complex compounds and reduced to far simpler forms.

(2) *Composition of organic matter.*—If certain organisms decompose organic matter, or tear it down, certain others compose it, or build it up. The simple nitrogenous compounds mentioned above are not yet in condition to be utilized by plants. Vegetation cannot feed on free nitrogen, nor on a slightly more complex compound called nitrites (salts of HNO_2), and if the nitrogen is left in these forms, the soil will rapidly lose its fertility. It is not infrequent that some fields will support only a scanty vegetation although analysis will show an abundance of nitrogenous compounds. In spite of the abundance of nitrogen the plants are nitrogen-starved, as is shown by the fact that the addition of a little nitrogen fertilizer produces a marked increase in growth. But frequently the addition of a little manure produces results far out of proportion to the actual plant-food added with the manure itself.

These facts are explained by the agency of another class of soil bacteria whose function is quite the reverse of the class just mentioned (in 1). These, called nitrifying bacteria, have a close relation to nitrogen compounds, but instead of decomposing them they bring about their union with oxygen. The ammonia, which contains no oxygen, is oxidized and converted into nitrites (salts of HNO_2) and by this means built upward one step toward usefulness. These nitrites are further oxidized by the addition of more oxygen and built up into nitrates (salts of HNO_3), and these nitrates are now in the best condition for assimilation and are thus finally once more in the form of plant-foods.

Nitrification.—This general process of union of nitrogen compounds with oxygen is called nitrification. It is the final step in the transformation of soil nitrogen into a condition for use, and is thus a necessity for the continuance of soil fertility. We can understand how the fertility of any soil will depend on the vigor by which this nitrification is promoted. Remembering that this process is dependent on the activity of nitrification bacteria, we can understand how the addition of manure to certain fields of low fertility may sometimes produce results far beyond expectation. The bacteria thus unlock the soil nitrogen and render it available.

The process of nitrification is at least twofold. Ammonia is oxidized into nitrites, and these nitrites are later oxidized into nitrates. Both of these processes are brought about by bacteria, and apparently different kinds of bacteria are required for the two processes. The nitrifying bacteria appear to be present in most soils in sufficient abundance, and commonly all that is necessary for their function is the proper conditions of growth. The conditions under which they act in the soil are complex and not fully understood, but one thing is certain: since nitrification is an oxidation, it follows that a good supply of air in the soil is a necessity for its active progress. Hence, in loose soil it takes place more readily than in soil closely packed; hence, also, the value of thorough cultivation. The thorough stirring of the soil, by plowing and cultivating, not only brings new soil to the surface and improves the moisture conditions, but it actually increases the amount of available plant-food by furnishing an abundant supply of air with which the soil bacteria can perform the process of converting the lower nitrogen compounds into nitrates. At present the most practical means of stimulating nitrification is by thorough cultivation. There is as yet no reason for believing that soil inoculation with nitrifying bacteria will be of much value.

The air as a source of nitrogen.—It is evident from the above that there will be a constant actual loss of nitrogen from the soil. The free nitrogen joins the air, and some of the ammonia does likewise. Much of the soil nitrates leaches into the streams, and anything that gets into the water-courses is lost to the soil. Unless, therefore, there is a means of reclaiming this lost nitrogen from the air, the cycle would not be complete and soil fertility would in time disappear. That there is such a means is evident from the fact that soil fertility has continued unimpaired for countless centuries. The secret of continued culture of the soil must be in learning and controlling nature's means of restoring the lost nitrogen. So far as we know at present, there are two primary means of such restoration, both of which concern bacteria. [See, also, the Editorial discussion in Chapter XIV.]

Certain species of bacteria in the soil are capable of direct assimilation of the atmospheric free nitrogen. This has been shown by the fact that soil deprived of all living organisms except bacteria will accumulate a store of nitrogen products, while similar soil, sterilized, and thus deprived of all living germs, fails to store nitrogen. With this fact as a start, bacteriologists have succeeded in isolating from the soil a group of bacteria capable of utilizing free nitrogen and fixing it in the form of solid compounds. To what extent this goes on in ordinary soil is not known, but evidence is accumulating to show that it is a phenomenon of more importance than at first supposed, and that a considerable part of the constantly renewed nitrogen supply of the soil comes from this source. No practical suggestion can yet be given for increasing this action.

A second method by which bacteria aid in gathering atmospheric nitrogen is through their relation to the root tubercles, developed chiefly on legumes. That certain leguminous plants (peas, beans, clover, alfalfa, and the like) have some close relation to soil fertility has been dimly recognized by agriculturists for some time (consult page 454), but it was reserved for the bacteriologist to explain the phenomenon and make practical application of it. It is now well known that the legumes are nitrogen-gatherers, and while growing actually increase rather than diminish the amount of available nitrogen in the soil. In addition to this, the legumes themselves become rich in nitrogen and form the farmer's richest proteid-bearing crop. This power of gathering nitrogen is associated with the well-known tubercles that develop on the roots, and these tubercles are dependent on certain soil bacteria. The bacteria in question

(*Bacillus radicicola*) penetrate the young rootlets and there develop as partial parasites. Their presence is useful to the legume, however, for it stimulates it to produce the tubercle within which the bacteria find lodgment; and under these conditions atmospheric nitrogen is seized and deposited in the legume. Whether the bacteria actually seize the nitrogen and hand it over to the legume, or the legume seizes it under stimulus of the bacteria, is unsettled, but the combined action certainly results in the fixation of this element. After the death of the legume the nitrogen compounds thus formed may undergo the transformations already noticed and eventually reach the condition of nitrates, thus restoring some of the nitrogen salts that constantly are being lost.

Most or all of the legumes have this power of acting with bacteria, but it has been a much discussed question whether the bacteria that act with the different species of legumes are the same or different species. Although this question is not yet positively settled, the evidence at present seems to indicate that the bacteria are only different varieties of the same organism. It is certain that different varieties or races of bacteria are demanded for the different species of legumes. Any legumes will flourish best in soil well-stocked with the variety of tubercle bacteria especially adapted to the species of legume. Inasmuch as it can not be expected that any soil will contain all varieties of these tubercle bacteria, it follows that some soils grow certain species of legumes better than others, even though the chemical composition is equally favorable to all. Hence has arisen the plan of inoculating soil with cultures of the varieties of bacteria especially adapted to the legume it is desired to cultivate. [See article on Soil Inoculation, page 447.]

It is a matter of importance that these bacteria act with legumes most vigorously in soils not already containing a good supply of available nitrates. Apparently the legume can secure its nitrogen more easily from soil nitrates than from the air, and will do so if they are present. In other words, the power of seizing free nitrogen comes into play in soils in which the nitrogen is needed, but not in soils already supplied. Legumes are thus special agents for increasing the fertility of soils that are too sandy and contain too little nitrogen. Legumes alternating with nitrogen-consuming crops will materially aid in keeping up a continued fertility.

Other soil ingredients and bacteria.

Our knowledge of the relation of bacteria to other substances than nitrogen is less complete. Soil is primarily ground-up rock, and the agents which reduce the rock are chiefly physical and chemical. The action of water and frosts, and the chemical action of the air, are doubtless primary agents in producing soil; but there are good reasons for believing that the bacteria in no inconsiderable degree aid in these processes. Certain bacteria appear capable of living on bare rock, feeding on what they obtain from the air and from water, together with what they absorb from rocks. Growing in these positions, they probably contribute to the disintegration of the rocks through the secretions which they produce. Whether this action is of importance is not yet known. But, whether or not bacteria aid in this way, they certainly do contribute to other changes of the minerals in the soil.

The rock phosphates are insoluble and not immediately available for plants, but when they are mixed with decaying organic matter they constitute a very useful source of soil phosphorus. This, of course, means that the bacteria at work in the decaying substances directly or indirectly act on the phosphates, rendering them soluble and available for plant-food.

The available amount of potassium is also in a measure dependent on bacteria. It is well known that quantities of potash are left after vegetable matter has decayed or has been otherwise destroyed, and such potash is one of the chief sources of this element for plants.

Sulfur and iron constitute two other important elements in plant-foods, although each is needed only in very small quantity. These two elements are constantly going through a series of transformations in cycles, in one phase of which they constitute plant-foods. Sulfates, for example, are seized by plants and utilized in building up their tissues. Later, when these plants are decomposed by bacteria, the sulfur is set free in the form of a gas (H_2S). This gas serves a certain group of soil bacteria as a food; the hydrogen and sulfur are pulled apart and the sulfur is deposited as pure metallic sulfur. Next, another group of bacteria utilize the pure sulfur, causing it to be oxidized by the oxygen of the air into SO_2, and this, by subsequent union with water, forms sulfuric acid and then sulfates. Uniting with the ammonia set free by decomposition, sulfate of ammonium may be thus formed. Later, these sulfates are again assimilated by plants in ordinary vegetation. These phenomena are especially prominent in the vicinity of the so-called "sulfur springs," but they doubtless occur in all soils where decomposition is taking place. Bacteria also contribute to produce a somewhat similar cycle of iron. This metal is obtained from rocks or soil by bacteria in the form of iron carbonate, utilized by the so-called iron bacteria, and eventually is converted into certain iron salts (sulfates, silicates), which can furnish vegetation with its supply of iron.

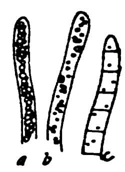


Fig. 613. Beggiatoa. One of the sulfur bacteria common in water in the vicinity of mills where sulfur is a waste product; also in glucose factories where sulfuric acid is used. The organism produces an odor of hydrogen sulfid. (*a*) A filament containing a large amount of sulfur. (*b*) A filament with part of the sulfur removed. (*c*) Filament with nearly all the sulfur removed. After Fischer.

It is extremely probable that certain other important changes in the mineral ingredients of the soil are brought about by bacteria, but the subject has not yet been thoroughly investigated. The facts already mentioned, however, show that all of the important plant-foods in the soil have very close relation to bacterial action.

Lessons from the study of soil bacterial action.

One of the most practical lessons to be drawn from this series of facts is the close dependence of soil fertility on cultivation. All of these activities of soil bacteria are dependent on soil conditions, and the necessary conditions are such as are brought about by the growth of vegetation. The more vigorous the vegetation, the greater the activities of the soil bacteria.

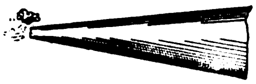


Fig. 614. The point of the finest cambric needle. A particle of dust above the point, and a mass of bacteria below.

Nature has solved this problem of soil fertility in the primeval forests and the prairies; and, while the intensive cultivation of a farm presents different conditions and more difficult problems, there is every reason for believing that the proper control of bacterial activities, with proper rotation of nitrogen-gathering and other crops, will make possible continued cultivation without exhaustion. Exactly how it is best to utilize these unlimited forces in the soil is not yet fully learned: whether by soil inoculation, by special forms of cultivation, by special rotation of crops, or otherwise; but there can be little doubt that the secret of successful agriculture in the future lies in the proper stimulation of the unlimited forces manifested by the soil bacteria.

Literature.

There are no American works on this subject except the bulletins published by the experiment stations. Several of the stations have issued such bulletins. For further information, the reader should consult: Die zersetzung der Organischenstoffe und die Humus Bildungen mit Rucksicht auf die Bodencultur, by Wollny, 1897; Flügge's Die Microörganismen, article by Gotschlich, 1896; Ann. d l'Inst. Past. IV and V, by Winogradsky, 1890–'01; Cent. f. Bact. u. Par. II, II, by Winogradsky, 1896; Cent. f. Bact. u. Par. II, IV, by Stutzer and Hartleb; Land. Jahr. XXVIII, by Kruger and Schneidewind, 1899; Cent. f. Bact. u. Par. II, VI, by Hiltner, 1900; Beilag. zur. d. Zeits. d. Ver Rubenzucker, Industrie, d. d. R., by Hellriegel and Wilfarth, 1888; Agricultural Bacteriology, by Conn, 1901; Microbiologie Agricole, J. B. Baillière et Fls. Paris, by Kayser, 1905. Figs. 609–612 and 614 are from Conn's Bacteria, Yeasts and Molds in the Home, Ginn & Co.

INOCULATION OF THE SOIL

By *Jacob G. Lipman*

Inoculation of the soil consists in the introduction into it of micro-organisms that will enhance its crop-producing power. There are records of soil-inoculations with decay bacteria, nitrifying bacteria, symbiotic nitrogen-fixing bacteria, and non-symbiotic nitrogen-fixing bacteria. It is still uncertain whether the introduction into the soil of ammonifying or nitrifying bacteria will prove practicable. The belief prevails among soil-bacteriologists that more is to be expected from soil-improvement than from soil-inoculation, since improved temperature, moisture and food conditions would naturally be accompanied by an increase in the physiological efficiency of the soil bacteria, while the introduction of vigorous organisms would hardly lead to better ammonification or nitrification without previous soil-improvement. The possibility is not excluded, at the same time, that future research will render such inoculation practicable, and that soil-amelioration accompanied by the inoculation, with vigorous strains of ammonifying and nitrifying bacteria, will enable the farmer to control with more certainty the rate of the decomposition of his soil humus.

Early studies in soil-inoculation.

While the attempts to promote decay and nitrification in the soil by inoculation with the corresponding organisms have been few, and the results for the most part negative, similar attempts with nitrogen-fixing bacteria, both symbiotic and non-symbiotic, have been numerous, and the results rather definite in certain directions. The soil-inoculations thus far made with non-symbiotic nitrogen-fixing bacteria, which included *Bacillus Ellenbachensis*, *Clostridium Pasteurianum*, *Azotobacter chroococcum*, *Azotobacter Vinelandii* and *Azotobacter Beyerincki*, have failed to yield positive results that could be attributed directly to the organisms in question. Commercial preparations of *Bacillus Ellenbachensis*, known as alinit, were placed on the market in 1897 by the firm of Friedrich Beyer and Company, of Elberfeld, Germany, the manufacturers asserting that their preparation would enable all crops, legumes as well as non-legumes, to make use of the free atmospheric nitrogen. Because of the importance of the question,

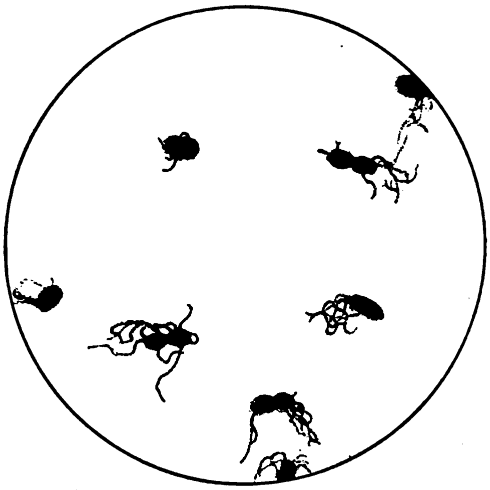


Fig. 615. One of the soil bacteria. Azotobacter agilis. Greatly magnified.

alinit was extensively tested in Germany, and to some extent also in other European countries, and in America. The various experimental studies in the field and laboratory failed, on the whole, to confirm the extravagant claims made by the manufacturers, and the cultures were subsequently withdrawn from the market. The studies of alinit also proved that *B. Ellenbachensis* is not a nitrogen-fixing organism in the sense that *Clostridium Pasteurianum* and allied species, or the members of the azotobacter group, are nitrogen-fixing organisms; and it became clear, thus, why alinit could not accomplish what had been asserted for it. On the other hand, the butyric ferments of the *Clostridium Pasteurianum* group, and the aërobic organisms of the azotobacter group, have been demonstrated to be capable of fixing very considerable quantities of atmospheric nitrogen when growing in artificial solutions in the laboratory; and observations prove almost with certainty that these organisms are at times responsible for large gains of combined nitrogen in field soils. At the same time, the cultures of these organisms hitherto used in pot and field experiments did not lead to an increase of crop. The wide distribution of these organisms in arable soils and the negative returns from artificial inoculation have led to the belief that also in this case more is to be expected from soil-improvement than from soil-inoculation. It should be noted here, however, that as in the case of the decay and nitrifying bacteria, the inoculation studies with *Clostridium Pasteurianum* and the various azotobacter species have been too limited in scope to permit a final conclusion.

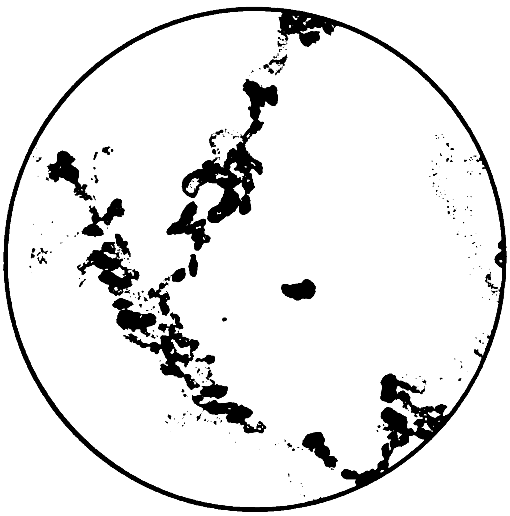


Fig. 616. Azotobacter Vinelandii. Greatly magnified.

By far the greater part of the soil-inoculation experiments hitherto recorded have been made with the symbiotic nitrogen-fixing bacteria. The work here has passed the purely experimental stage, and there is no longer a doubt that under proper conditions soil-inoculation for legumes may prove very effective. The earlier inoculations for legumes were made with old legume soils or with leachings from such soils. Hellriegel and Wilfarth, for example, used such leachings for inoculation purposes in the middle eighties of the last century. A few years later, practical farmers in Germany were also using soil from old legume fields for spreading on other fields where the same legume had not been grown previously. Thus, Salfeld reported, in 1892, that the yield of peas on a new field could be very markedly increased by having spread on its surface some soil from another field that had previously borne good crops of peas, and recommended the use of about four hundred pounds of soil per acre. Subsequently the use of old legume soil for inoculation purposes became rather general. Variations of this method were also introduced in having the legume soil stirred with water and the seed moistened with the soil infusion thus produced, or the seed was intimately mixed with a small quantity of such soil made barely moist. The original method of soil-inoculation is still widely used, especially in Germany, in connection with lupines, vetches and serradella, and in this country for starting new fields of alfalfa.

Experiments by Nobbe and Hiltner in Germany.

It became apparent before long that the use of soil for inoculation purposes had its serious disadvantages. Such soil is not always conveniently accessible, the handling of the comparatively large quantities of material involves a considerable expenditure of money and labor, and there is always the danger, moreover, of introducing noxious weeds and fungous pests. These considerations led Nobbe and Hiltner to experiment with pure cultures of the nodule bacteria as inoculation material. As the result of their investigations there appeared in the middle nineties the commercial preparation "nitragin," manufactured by the firm Meister, Lucius and Brünning, of Höchst, Germany. Nitragin was a pure culture, on nutrient gelatin, of *Bacillus (Pseudomonas) radicicola*, adapted in each case for

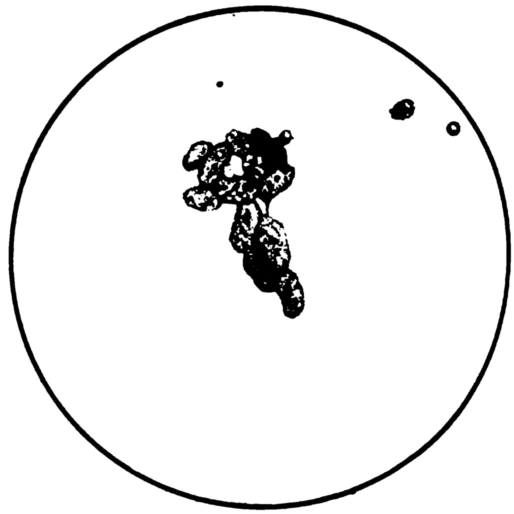


Fig. 617. Azotobacter Beyerincki. Greatly magnified.

any one particular legume. The gelatin culture was contained in a glass bottle originally stoppered with a cork, but later with a cotton plug to facilitate the circulation of the air. The directions called for a solution of the gelatin in water and the moistening of the seed with the resulting liquid. With but few exceptions nitragin failed to yield satisfactory returns, its manufacture was discontinued, and soil-inoculation with pure cultures was largely discredited. The originators of nitragin felt convinced, however, that the use of pure cultures could be made practicable. Further study proved to them that the failure of nitragin was due to the deterioration of the culture on the highly nitrogenous gelatin. They then tried a number of different culture media, finally substituting agar for gelatin, and introducing the use of legume extracts together with the agar. They also found that the distribution of the agar culture in plain water, previous to the seed inoculation, frequently led to the weakening or the destruction of the bacteria, and hence suggested the use of salt solutions or of skimmed milk. The new nitragin thus gradually evolved has proved eminently satisfactory, since over 80 per cent of the inoculations in Bavaria for 1903 gave an increase in yield over the corresponding non-inoculated soils. The returns are the more promising in view of the fact that an increase was obtained in many instances on old legume soils.

The method devised by Moore in America.

The use of pure cultures for soil-inoculation was also made the subject of an extensive study by the United States Department of Agriculture. The method developed by Moore was rather different

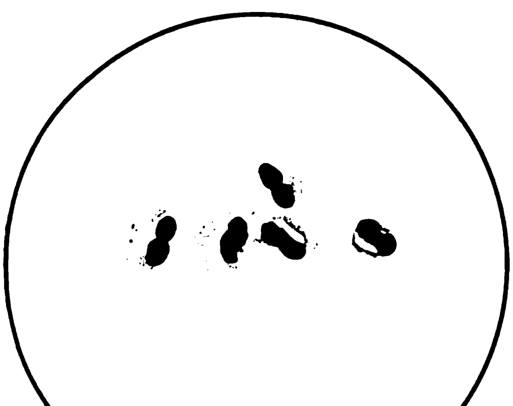


Fig. 618. Azotobacter chroococcum. Greatly magnified.

from that outlined above. Instead of preparing gelatin or agar cultures ready to be distributed in water or some salt solution, Moore provided material for the cultures, rather than the cultures themselves. This material, as sent out, consisted of a piece of cotton previously immersed in, or sprinkled with, a pure culture of the nodule organism, and later dried; and also of weighed quantities of sugar, potassium phosphate, magne-

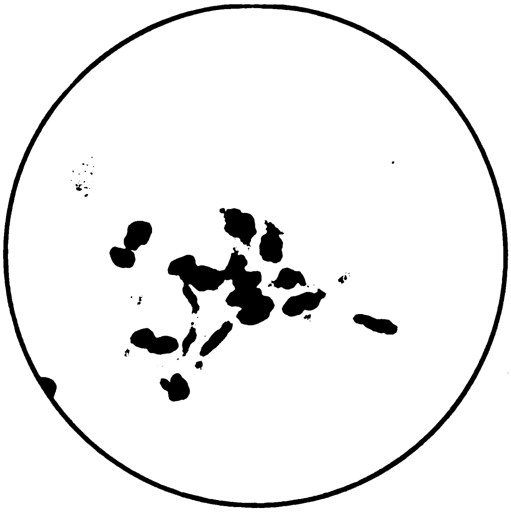


Fig. 619. Azotobacter Woodstoronii. Greatly magnified.

sium sulfate and ammonium phosphate. The cotton containing the dried organisms was to be placed in the solution of sugar, potassium phosphate and magnesium sulfate, and the ammonium phosphate was to be added to the solution about twenty-four hours later. It will thus be seen that Moore's method leaves the preparation of the liquid cultures to the farmer. The latter is instructed to use a measured quantity of water, to observe certain precautions as to light and temperature, and to consider the fluid as suitable for inoculation purposes when it assumes a milky appearance, which occurs in two to four days. This method is open to serious criticism, because it leaves the performance of bacteriological work to untrained persons. Assuming even that the desiccation on cotton does not in the least reduce the vitality of the bacteria, it still remains true that the introduction of the cotton into water which the directions merely designate as clean, and which, whether spring or well water, must of necessity contain considerable numbers of various organisms, cannot lead to the formation of a pure culture of the nodule bacteria. Contamination from the water, air and the vessels used, in the presence of the nutrient salts employed, may (and usually does) lead to the development of a vigorous flora of various micro-organisms that may partly or wholly suppress the nodule-forming bacteria. The farmer has no means to ascertain the exact nature of his culture, for the milky appearance may be due to the vigorous growth of yeasts, or bacteria quite different from *Bacillus* (*Pseudomonas*) *radicicola*.

Comparison of German and American methods.

The main difference, therefore, between the German and the American method of soil-inoculation with pure cultures lies in the fact that the former supplies to the consumer a culture of the nodule organisms in numbers sufficiently great to allow an immediate inoculation of the seed; whereas the American method provides only a comparatively small number to be used as a starter in working up a large volume of culture solution. Also, the German method has its imperfections. The use of solid culture media like agar allows the concentration in the zone of growth of the products of bacterial metabolism, which may affect unfavorably the vitality of the organisms.

The future of inoculation.

Notwithstanding these imperfections, it is already certain that the use of pure cultures of legume bacteria will steadily increase with the improvements in the methods that will surely come. Inoculation will become more general, not only on soils newly placed under cultivation, but also on old legume soils; for it has been demonstrated that on suitable culture media the physiological efficiency or virulence of the bacteria may be markedly increased and maintained for a long time. The use of such bacteria will make possible, therefore, a much larger accumulation of nitrogen than could be secured through the organisms spontaneously occuring in the soil, in a given length of time. Moreover, the mere introduction of large numbers of efficient bacteria, though they be no more efficient than those already present, assures the proper inoculation at the time when it is most needed.

Literature.

A great deal has been written on this and allied subjects in European countries, notably Germany, but American literature on the subject is still meager. The following references are given for further information: Soil Inoculations with Members of the Azotobakter Group, New Jersey Station Report, 1904, page 279, by Lipman; Versuche über die Stickstoff Assimilation der Leguminosen; Landwirts. Versuchs. by Nobbe, Schmidt, Hiltner and Hotter, 1891. Vol. XXXIX; Ueber die Dauer der Anpassungsfähigkeit der Knöllchenbakterien an bestimmte Leguminosengattungen; Landwirts. Versuchs. Vol. XLIX, by Nobbe and Hiltner; Wie lässt sich die Wirkung des Nitragins erhöhen? Landwirts. Versuchs. Vol. LI, by Nobbe and Hiltner, 1899; Ueber die Ursachen, welche die Grösse, Zahl, Stellung, and Wirkung der Wurzelknöllchen der Leguminosen bedingen; Arbeiten aus der Biol. Abt. f. Landwirts. und Forstwirts. am Kaiser. Ges.-Amte, Vol. 1, No. 2, by Hiltner, 1900; The Inoculation and Cultivation of Alfalfa, Bulletin No. 154, Virginia Experiment Station, by Soule and Ferguson; Soil Inoculation for Legumes, Bulletin No. 71, Bureau of Plant Industry, United States Department of Agriculture, by Moore; Soil Inoculation for Leguminous Plants, Bulletin No. 87, Alabama Experiment Station, by Duggar; The Quality of Commercial Cultures for Legumes, Bulletin No. 270, New York Experiment Station, by Harding and Prucha; Inoculation of Legumes, Farmers' Bulletin No. 240, U. S. Dep. of Ag.

SOIL DISEASES

By *F. L. Stevens*

The term "soil disease" in its broadest sense may include any condition of soil that renders it unfit for the production of a specific plant in its maximum state of perfection. In such broad sense would be included all lack of proper chemical constituents, presence of undesirable substances, improper physical condition of the soil, presence or absence of certain bacteria or fungi, the presence of moles, worms, and other devastating animal enemies to plant-life, and the prevalence of weeds or weed seeds. The consideration of all these varying factors here would lead too far afield, and the subject for the present purpose is limited to a much narrower sense; viz., to those conditions of soil brought about by the presence of organisms capable of living parasitically on cultivated plants, thus inducing diseases. The discussion of subjects closely akin to this may be found in preceding and succeeding articles.

Fig. 620. Young nematode. Enlarged.

Classes of soil disease-producing organisms.

Soil diseases in the sense defined above are caused chiefly by three classes of organisms: bacteria, fungi and nematodes.

Fig. 621. Young nematodes entering cucumber root tip. Enlarged.

Nematodes, or "eel worms," are minute worms barely visible to the naked eye, similar to the "vinegar eel," so often noticed in vinegar. There are many species of nematodes, but only one seems to do injury to plants. This form lays an egg about $\frac{1}{250}$ of an inch in length. Within the egg the young worm develops, eventually escaping by rupture of the shell. It is then about $\frac{1}{75}$ of an inch in length. In structure it is simple, consisting of a body wall containing the alimentary canal and very simple sexual organs. Within the mouth is a spear-like organ that assists in penetrating roots. The young are hatched in great numbers in the galls of roots, escape by decay of the gall, and wander about in the soil until they find suitable roots to attack, or rest in the soil. Having gained entrance to the root of a suitable plant, gall formation follows, and the worm develops to sexual maturity within the gall. Fertilization occurs and eggs are produced to initiate a new generation. The nematode is shown in Fig. 620; and injuries by it in Figs. 621–623. In Fig. 621, two nematodes are shown at the tip of the root.

Fig. 622. Nematode galls on a young tomato plant.

Importance of the study of soil diseases.

Soil diseases prevail on staple crops in every part of the country where cultivation is practiced,—in the North the flax wilt, in the East the onion smut, in the South the wilts of the watermelon, cowpea and cotton, and everywhere the crown-gall on a variety of hosts. The following is an incomplete list of plants affected by soil diseases: potato, tomato, cowpea, various clovers, sunflower, watermelon, citron, cabbage, fig, peach, grape, egg-plant, cotton, okra, turnip, beet, parsnip, carrot, salsify, flax, ipomœa, clematis, abutilon, violet, rose, tobacco, corn, lettuce, horehound, cyclamen, coleus, heliotrope, spinach, begonia, cauliflower, radish, apple, sweet-potato.

The variety of plants attacked by soil diseases, the importance of the crops and the range of territory occupied, render them of special importance. Their chief claim to attention from an economic point of view lies in the fact that they stand not merely for the loss of a single crop, but for the loss of the affected land for the purpose of raising the susceptible varieties of plants for years, often for decades. If the susceptible crop is one of high importance in the community, if it is one of the staple crops, such as cotton in the South, flax in the Northwest, onions in the trucking regions, or if it be the only money crop, as tobacco in the "bright tobacco belt," the depreciation in the market value of the land is very marked, often as high as 50 or even 70 per cent.

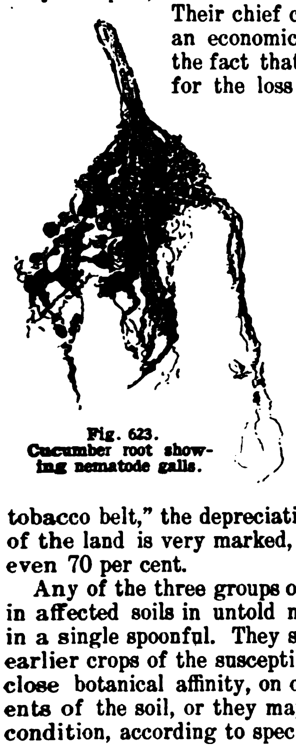


Fig. 623. Cucumber root showing nematode galls.

Any of the three groups of organisms may reside in affected soils in untold numbers, often millions in a single spoonful. They subsist on the debris of earlier crops of the susceptible plants, on plants of close botanical affinity, on other organic constituents of the soil, or they may remain in a dormant condition, according to specific habits.

How the organisms work.

When plants subject to attack are grown in infected soil, and the roots and the disease-causing organism come into contact, the parasite penetrates the roots, or the stem near the surface of the ground, and induces the disease.

In the case of nematodes, the response of the plant to attack usually consists in accelerated growth of the adjacent cells, resulting in gall formation such as is pictured in Fig. 623, each gall usually marking the point of primary entrance of a nematode.

Certain fungi produce galls of somewhat similar general appearance, as the crown-galls, Fig. 624. The entrance of bacteria or fungi, however, usually produces no such symptoms, nor do the organisms remain local. They usually migrate by growth through the root tissues until they gain access to the veins. In these open passages they increase and rapidly extend longitudinally throughout the plant. So rapid is the growth of the parasite, whether bacterial or fungous, that the veins soon become to a large extent plugged, often so completely that the rise of the sap in the plant is entirely cut off. This interference usually results immediately in a wilting of the foliage, hence the name "wilt" so widely and appropriately applied to these diseases. The wilting thus occasioned often occurs so suddenly that a whole melon vine, apparently sound, in two hours' time may collapse as though cut from its roots, and in the course of a few hours become merely a shriveled dead vine. A wilt disease is shown in Figs. 625, 626.

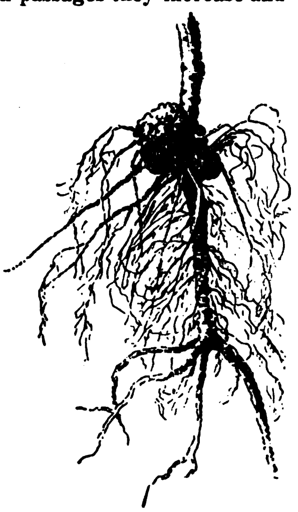


Fig. 624. Hard crown gall on grafted tree at union of scion and root.

One class of soil diseases known as "damping off," is caused by fungi from the soil invading the stem tissue near or at the surface of the ground, there causing a softening or rotting with the result that the plant falls over and dies. Similarly in the cutting bed, tender, wounded, poorly nourished, struggling stems and buds succumb to a rot induced by germs from the soil.

Fig. 625. Tobacco plant affected with the Granville tobacco wilt.

Soil diseases in general may be recognized by two characteristics: first, repeated occurrence of the disease year after year in the same areas; second, the gradual enlargement of the affected areas in all directions.

Means of dissemination.

In general, anything that leads to a distribution of diseased soil or diseased plants in unaffected soil brings about a spread of the disease. Some of these means are obvious; for example, washing from higher to lower lands. It is frequently noticed that when the higher lying fields become affected, the adjoining lower lands first show disease in those parts receiving drainage water from the diseased lands. Soil adhering to tools, plows, cultivators, hoes, to the feet of animals or man, may similarly carry contagion. Also, instances are known of soil to be used for inoculating fields with root tubercle germs having been taken from fields infected with

Fig. 626. A field showing prevalence of the Granville tobacco wilt.

a soil disease, and having produced infection on the field to which it was applied. In greenhouses, hotbeds and similar places where "made soil" is used, the disease will of course be carried if any of the soil used be from a contaminated source.

Diseased plants may serve as carriers of the germs in many ways. Of these, transplanting is one of the most important. Plants from a diseased seed-bed, as in the case of clubroot of cabbage and other crucifers (Figs. 627, 628, 629), may carry contagion to previously healthy fields. Nursery stock from rows affected by crown gall may lead to dissemination of the pest. Dissemination by soil-inoculation and by seedlings and nursery stock is particularly effective and far-reaching, owing to the distance which such carriers are likely to be shipped; even a world-wide distribution might readily result in the case of an aggressive soil disease occurring on a variety of plant which is extensively exchanged from country to country, unless proper supervision is exercised to prevent such dissemination.

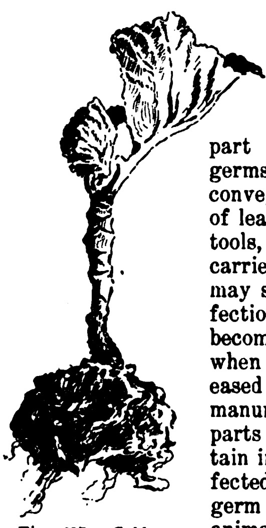


Fig. 627. Cabbage plant badly affected with club-root.

Dead plants, each small part bearing millions of the germs of disease, may similarly convey the disease. Broken bits of leaf, twig or root adhering to tools, caught by the wind or carried by a careless passer-by, may start a new center of infection. This mode of spreading becomes particularly important when the dead parts of the diseased plants have feeding or manurial value. If infected parts be used in manure, certain infection will result. If infected parts be used as feed, the germ may pass through the animal in a viable condition, or, in cases when this is not possible, bits of germ-laden refuse may find their way from the manger to the manure-heap, where as a rule they will remain alive for months, and where they will in many instances even grow and multiply. Dissemination in this way is frequent in the case of the cruciferous clubroot, as when the refuse leaves, stalks and heads of infected cabbage are fed to stock. It is also an especially prominent and noteworthy method of dissemination of the watermelon wilt, owing to the peculiar method of rotation almost universally practiced with that crop. It is customary to sow cowpeas among the melons and to cut the cowpea hay after the melons are harvested. If there are diseased melon vines among the cowpeas, these will be raked with the hay, and thus find their way to the manure-heap. The fungus causing the melon wilt finds congenial environment in the manure and in the barnyard, and there multiplies extensively, soon thoroughly infecting the whole pile and even the whole yard. If this infected manure be removed and fresh uninfected manure be placed in the same yard, this in time will also become infected. Thus a yard once infected will, unless unusual precaution be observed, become a perennial source of contamination. Manure thus infected affects fields on which it is applied. This method of distribution is much more than local, owing to the shipping of hay long distances, perchance to a city livery-stable and the subsequent shipment of the infected manure in various directions and often to great distances.

Fig. 628. Roots of hedge mustard affected with club-root.

While conveyance of germs, germ-laden soil, dust, and infected bits of plants by winds is theoretically possible, fortunately but little practical damage seems to come about in this way; otherwise the search for methods to prevent dissemination would be well-nigh hopeless.

The longevity of the germs in soil varies with the species and the conditions. If a suitable host-crop is on the soil, all of them are probably capable of indefinite existence. Some species of germs will die within a few years if deprived of their host-plants; other species live many years. Many are well-nigh omnivorous and can subsist on almost any organic substance; others are extremely exacting and require their own host-plant if they are to multiply. Many species can lie dormant in a soil for long periods. Much remains to be discovered concerning the longevity of germs in soil, and the condition necessary to their multiplication. In general it may be said that soil diseases usually persist in affected fields for years if suitable environment obtains. The map in Fig. 630 shows how widely a disease may be disseminated.

Means of prevention.

With soil diseases it is, above all, necessary to prevent rather than to rely on treatment after the soil becomes diseased. This is true both because of the inefficiency of the treatments and the efficiency of prevention.

In general, the means of prevention may be inferred from the paragraphs on dissemination.

Fig. 629. Stages in the life of the germ that causes the clubroot of cabbage, turnips and other cruciferous plants.

Every precaution to guard against the dissemination of the disease should be taken. This includes a watchful care over manures to guarantee their freedom from germs. The use of commercial fertilizers, when uncontaminated manures cannot be secured, is by far the safest method. Spread of the disease by washing of the land may often be prevented by suitable dikes or terraces, and spread by means of dirt on tools by careful cleaning, followed by sterilization, that is, by a washing in 5 per cent carbolic acid before passing from infected to healthy soil. Care should be taken to convey as little infected dirt as possible on the feet of workmen and domestic animals. If soil is to be used in inoculation for legumes, it must come from unaffected fields. Plants and nursery stock from diseased fields must be carefully guarded against. With these precautions, the encroachment of the disease on new territory may be greatly retarded or altogether prevented.

Treatment of affected soils.

Many chemicals and mixtures have been applied to soils with the hope that thereby the disease germs might be killed, but in few instances has this proved effective. The use of lime in large

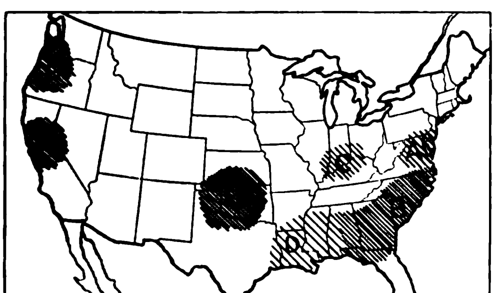


Fig. 630. Distribution of watermelon wilt in the United States.

quantities for clubroot of the crucifers and of sulfur for onion smut nearly comprises the list of such remedies. In most cases chemical treatment of soils is barren, although applications of carbon bisulfid are reported to have been efficacious on grape-sick soils in parts of Europe. When the amount of soil to be treated is small, as in a greenhouse, sterilization by heat is sometimes practicable; or the soil may be completely removed and the benches sterilized by a heavy application of copper sulfate followed by lime. The benches may then be refilled with unaffected soil.

Crop rotation, employed in order to deprive the germs of their sustaining host, will in many cases bring about either total or partial recovery. This is notably true concerning the clubroot of crucifers. In cases when crop rotation is not wholly effective, it may so far result in the recovery of the soil as to enable the susceptible crop to be raised once in each three or four years without serious prevalence of disease. In the employment of crop rotation, weeds or cultivated plants of close

Fig. 631. Iron cowpea and Black and Taylor, showing comparative resistance of the Iron to wilt and root-knot.

botanical affinity to the affected crop plant must be zealously guarded against. A wild weedy crucifer may harbor the germs of the clubroot, or a weedy relative of the tomato may keep alive the tomato-wilt parasite.

Immunity by plant selection.

In the case of most soil diseases, the greatest promise lies in the development of immune varieties by proper selection. With many kinds of plants there is a more or less marked variation in the degree of susceptibility. Some varieties under cultivation are highly immune and others very susceptible. By yearly selecting seed from the plants showing the greatest resistance, the immunity may be increased until perfect resistance is secured. A cowpea, "The Iron" (Fig. 631), resistant to both the root-knot (nematodes) and the wilt (fusarium), has been called to the attention of farmers by the United States Department of Agriculture. A cotton plant resistant to the cotton wilt has also been evolved by the Department. Other diseases are being experimented on, with the same end in view.

Literature.

The literature on soil diseases is scattered in the bulletins of the state experiment stations and the United States Department of Agriculture, and the agricultural experiment stations of foreign countries. Especially important among these are the publications of the Massachusetts station on nematodes; of the Bureau of Plant Industry on the wilt of cotton, cowpeas, watermelons, tomatoes and other plants; and of the Mississippi Valley Laboratory on crown gall.

CHAPTER XIV

TREATMENT OF THE SOIL BY MEANS OF FERTILIZING AGENTS

ADDING PREPARED MATERIALS TO THE SOIL for the conscious purpose of increasing its plant-producing capabilities is a very modern practice. It rests on the development of that collection of studies known as agricultural chemistry; and agricultural chemistry, if we begin it with Sir Humphrey Davy, is just now entering its second century. With the study of the composition of the soil and of plants, there developed the idea of a fertilizer founded on a formula. The fertilizer conception rests on the soil-depletion idea,—on the assumption that the soil is a fairly constant compound of substances, and that the plant takes certain of these substances into its own tissues and becomes the vehicle of their removal. The loss is to be made up by some material applied to the soil. The very process of soil formation itself has been exceedingly wasteful of plant-food materials from the cultivable lands, as Dr. Merrill's article in Chapter X will show. Fertilizing, in the old sense, is a problem in addition, so far as farm-practice is involved.

This conception of fertilizer-practice is now challenged; and in the conflict with other ideas the subject is confused even to the student, and the definiteness and positiveness of the advice of a few years ago have passed. Undoubtedly we shall settle again to some assured opinion; and in time we shall probably also again find ourselves in doubt as to the underlying reasons. The laboratory studies are now supplemented by field tests as they never were before, and this fact is insuring all results. The history of the ideas of fertilizing land is itself a profitable field of inquiry. The movement of some of these ideas may be briefly indicated in a rapid sketch of the quest of nitrogen, which seems to be the most elusive of the elements that the farmer needs to supply for his crops.

The early experience.

It has been the experience of mankind from the first that lands under crop gradually lose their crop-producing power, and that these lands tend to recuperate when left to themselves. How to account for these phenomena, and how to retard or prevent the deterioration of the land, have been questions of the first magnitude for thousands of years, for civilization rests on the land. A full account of the various attacks on this problem would develop one of the most interesting histories in the affairs of the race. The problem has enlisted not only many of the wisest men, but it has absorbed the attention of even the major part of mankind; for by far the greater number of men have lived on the bounty of the soil, and their accustomed work has been an effort to maintain that bounty.

When history opens, the results of experience with the land had been crystallized into customs. One of these customs was a rotation, or succession, of crops; and one part of the rotation was a "fallow," or idle year; and another part, in many cases, was the growing of some kind of pea-like plant. Experience had shown that this order tends to preserve the productive power of the land. Later on, it developed that the tilling or stirring of the land has a conserving or even a recuperative effect; and, in time, tillage came to be employed for the sake of tillage, and not merely as an aid in fitting the land to receive the seed or as an agent in destroying the weeds. It was also early discovered that the application of animal excrement augments productiveness.

The chemical explanation.

The development of natural science began to add explanation to the old empiricism. It was discovered that certain elements composing the earth and the air are indispensable to plants; and little by little it was determined how the plant appropriates these elements. Certain of these elements are so universally abundant in usable form that the husbandman does not need to consider them; but others are either in danger of being greatly depleted or are normally in unavailable condition. It is to these special elements, therefore, that the attention of agricultural scientists has been chiefly directed. Most of these particular elements are integral parts of the soil itself, but one of them—nitrogen—is derived directly or indirectly from the air. The nitrogen is therefore an extraneous soil element; and its compounds tend to be dissipated by chemical changes and by drainage waters. It therefore comes that the subject of greatest investigation and discussion is the nitrogen supply,—a fact all the more striking because the great bulk of the air itself is nitrogen.

It was the first and natural assumption that plants secure their nitrogen, as they do their carbon, directly from the air. But more than a hundred years ago, this was challenged; then for a generation or more it was alternately affirmed and denied. The classic experiments of Boussingault, completed about 1850, seemed finally to determine that the nitrogen of the air is not used by plants. At this time, the theory of the chemical or artificial restoration of the soil was gaining full headway, under the leadership of Liebig and others; and the nitrogen supply was sought from extra-agricultural sources. The first great source of commercial nitrogen was Peruvian guano, which, long known to natives of South America and studied by von Humboldt as early as 1804, began to acquire great importance in European and American agriculture about the middle of last century. For about a generation of men, this material seems to have held the major place in all schemes of artificial fertilizing of the land. As the supply of guano began to fail, nitrate of soda, discovered in vast deposits on the western coast of South America, came gradually to be utilized, and it is to this day one of the chief sources of high-grade nitrogen fertilizers. Another great source of nitrogen developed in the sulfate of ammonia, a by-product chiefly of the manufacture of illuminating gas. All the unburned fertilizers derived from animal sources—as bones, dried blood, and the like—also contain nitrogen, as do also the farmyard manures.

But the direct buying of fertilizing materials in large amounts does not contribute to the development of a self-sustaining agriculture, and can hardly be looked on as a permanent means of maintaining the productivity of the land. In gardening and other special-crop practice, heavy artificial fertilizing may be profitable, because of the high market value of the crops and the extra care given to tillage; but these conditions do not exist in general farm practice. Therefore, the mere introduction of nitrogenous fertilizers did not settle the question of the nitrogen supply; moreover, the actual bases of the nitrogen question were really not discovered, as many discrepancies in scientific results tended to show; and, again, the old belief that fallow land improves in its quality, and the experience that pea-like plants enrich the land on which they grow, were not yet explained. Some investigators concluded that the nitrogen brought down by the rains and snows in the form of atmospheric ammonia is the source of the constantly recuperating supply. It was said, for example, that "snow is the poor man's manure." It was soon determined, however, that this source of nitrogen is wholly inadequate to account for the amount gained by the soil, and the old adage was transposed to mean that the man who depended on the snow would be poor.

It was also supposed that natural electrical discharges are agents that combine the atmospheric nitrogen into such compounds as to render it available to plants. It is an old fancy that lightning enriches the earth; and, in fact, it is now known that there is some truth in this idea. The recent experiments of Lemström and others show that electrification of the atmosphere increases the growth of plants under certain conditions; but even this does not account for all the nitrogen supply of plants. The reader may remember the recent announcement of the startling experiments at Niagara Falls, whereby nitrogen compounds were made from the air by means of very high-tension electrical discharges. This feat was hailed as a solution of the great problem of the world's supply of nitrogen; and it aroused added interest because it came so soon after the striking assertions by Sir William Crookes, to the effect that the hope of the race lay in finding a practicable source of nitrogen. Very decided progress has been made within the last three years in the preparation of nitrogen compounds from atmospheric sources, and two such compounds are actually prepared, on a commercial scale, for agricultural purposes. The first of these compounds, calcium cyanamide, is made after a process reported by Frank in 1903. It is formed when atmospheric air, freed as far as possible from its oxygen, is passed over heated calcium carbide. When applied to the soil the calcium cyanamide is gradually changed there into ammonium compounds. The second of these compounds, sold as basic lime nitrate, is made in Norway after the Birkeland-Eyd patent process. The nitrogen and oxygen of the air are made to combine by electric discharges, the arc being spread out by electromagnets over a large surface. The large contact-area allows a very extensive oxidation of the nitrogen. The nitric oxid is dissolved in water, and the resulting nitric acid is concentrated and brought together with an excess of lime. The dried product consists of a mixture of lime and lime nitrate. Both of these nitrogen compounds are used on European farms.

The biological explanation.

As early as thirty years ago, it began to be seen that the nitrogen question lay beyond the reach of chemical means alone. Germ life in its many aspects began to be studied, and it was found that the soil is not a mere mixture of chemical compounds, but is also a scene of life. The question of the natural nitrogen supply became divided into two parts—the changing of various forms of organic nitrogen (as it occurs in compounds, in plants and animals) into such form that it can be again taken up by plants; and the appropriation, or "fixation," of the free nitrogen of the air. The former category is the phenomenon of nitrification—the making over of nitrogen compounds into nitrates (in certain combinations with oxygen). It is in the form of nitrates that nitrogen is chiefly used by plants. This process is now known to be the work of germs, or certain kinds of soil bacteria. These germs thrive best under certain conditions of temperature, soil moisture and aeration, and these conditions are provided and maintained by the accepted methods of tillage. Thorough and careful tillage, therefore, is, in this respect, a means of supplying usable nitrogen; but nitrification only works over nitrogen that has already been appropriated, and, therefore, does not add to the original supply.

Another step was the discovery that some germs have the power of appropriating the uncombined nitrogen of the air. These germs are in the soil, and they therefore draw on the air that lies in the interstices of the soil. The old belief that fallow land gains in nitrogen finds here at least a partial explanation; the germs appropriate the nitrogen, if soil conditions are right, and there are no crops to use it and, therefore, to remove it, although in some cases it may be partially leached away or lost by conversion into free nitrogen.

The most important advance, however, was the discovery, in 1888, that similar germs have established a very intimate partnership with the pea-like or leguminous plants: the germs appropriate the nitrogen, and pass it over to the plant for use; the plant, at the same time, provides a breeding-place and laboratory for the germs. Why this partnership has been established with the legumes and not with other plants, is a question for the future to answer. The general details of this co-partnership must be already familiar to attentive readers. The germs live and multiply in the nodules on the roots of clover, alfalfa, beans, and related plants, drawing their nitrogen from the air in the soil. Certain legumes seem to have their own kind of bacteria; the germ that has lived on the red clover root, for example, does not live on the alfalfa root, although it is thought that the normal alfalfa germ lives also on the sweet clover, or melilotus. It has been generally held that, if these leguminous plants are grown in soil that is rich in available nitrogen, they acquire very few tubercles and the growth is normal; but if the soil is poor in nitrogen, as many soils are, that they may still thrive if tubercles are present, whereas other plants will not. The host plants store this nitrogen in various compounds; when the plants or their stubble and roots decay, the nitrogen compounds are incorporated with the soil; nitrification intervenes, and the succeeding crop gets the benefit. It will be seen, therefore, that this partnership or symbiosis of legume and germ may increase the legume crop and, at the same time, add to the store of usable nitrogen in the soil.

It has been a persistent opinion of farmers that lime often adds to the productiveness of the land. One of the first American agricultural books ("An Essay on Quick-Lime as a Cement and as a Manure," by James Anderson, L.L.D., Boston, 1799) was devoted to this subject. Compounds of calcium (the basis of lime) are normally present in liberal amount in all agricultural soils, and therefore the agricultural chemists for many years controverted the idea that liming is beneficial to any important extent. It is now known that some germs do not thrive in an acid soil, and it is probable that some of the benefits of liming arise from the influence of the lime in correcting the acidity, and thereby making it possible for certain germs to thrive. It is therefore seen that even the old practice of liming has relation to the nitrogen supply.

In all normal soils the nitrifying bacteria are present. In all soils, also, the nitrogen-fixing bacteria are probably present. But not in all soils are there specific clover bacteria or cowpea bacteria or alfalfa bacteria. When the bacteria are absent and the soil is lacking in available nitrogen, these crops do not "catch," and it is necessary to supply the germs to the soil; and, inasmuch as the nitrogen supply is augmented very rapidly by means of the leguminous crops, it becomes a most important question as to just how the germs are to be supplied. And here we come to the most recent great innovation in agricultural practice—the so-called inoculation of the soil.

The inoculation idea.

The belief that the soil can be inoculated to advantage with germs is even older than the discovery of the partnership between germs and legumes. It was early predicted that land would be sown with nitrifying bacteria. Thus, Maxwell T. Masters, the English botanist, wrote as early as 1884 in his "Plant Life on the Farm":

"It is probable in the future that just as the brewer uses his yeast to secure the conversion of starch into sugar, and the chemist 'seeds' his solutions to effect the changes he wishes to bring about, and just as the gardener sows the spawn or germs of mushrooms in his mushroom bed, and obtains thereby a crop of succulent fungi, so the farmer may be able to supply to the soil the ferment-producing germs needed to change its quality, and render it available for plant-food. When we have arrived at that point, manuring will be reduced to a science, and a pinch of the right material will be as efficient as a ton of our present compounds, the larger part of which are undoubtedly wasted under existing circumstances."

The isolation of the nitrifying and nitrogen-fixing germs has led to the cultivation of the organisms in special media, and, in at least three instances, special preparations of these germs have been made for the purpose of inoculating land. Two of these preparations are of European origin, "alinit" and "nitragin." These failed to give the results in practice that were expected of them, and have been abandoned. In the past three or four years there has grown up a method of inoculating lands intended for alfalfa with soil from successful alfalfa fields, and this has given such satisfactory results that it has already become an accepted part of good farm practice. The method is applicable also to other leguminous crops. There is some labor and expense connected with the securing and sowing of the soil, but it is usually small in comparison with the results secured. It is said that there is danger of distributing weeds and fungous diseases with the soil; although this danger may not appeal to the general farmer, it is always well to take care that the soil comes from a clean farm. How important the soil diseases are, and how easily disseminated, may be learned from Mr. Stevens' article in Chapter XIII.

The question arises as to whether the seed, rather than the land, may not be inoculated. In some cases, sufficient soil and dust may go with the seed to supply the necessary germs. This was found by the Illinois Experiment Station to be the case with cowpeas, but not so with soy beans. It is a question whether it is true with alfalfa. The general practice now is, among advanced farmers, to inoculate the land with soil, in case the field has not grown the particular crop for four or five years. One advantage of putting clover in the rotation is that it keeps the soil in a continuous state of inoculation for clover, the germs living from one course to another.

The most recent development in the United States is the recrudescence of the idea of inoculating directly by means of pure cultures of the germs. This is the result of work in the United States Department of Agriculture. A study of germs as related to the nitrogen supply was made by Dr. George T. Moore and others. The conclusion was reached that there is only one species, but that this species has different infective power according as it has lived on one host or another. It was suggested, also, that one reason why the old "nitragin" was unsuccessful is because the germs were cultivated in a nitrogenous medium and the germs became, so to speak, nitrogen-surfeited. They were therefore cultivated in the Department laboratory in nitrogen-free media and the germs thereby were thought to remain active. The cultivated germs were incorporated, in a desiccated state, with absorbent cotton, so that they can be sent by mail and then be used for the inoculation either of the soil or of the seed. The cotton is thrown into water (which is prepared by treatment with certain chemicals) and, when the germs have multiplied sufficiently to make the water cloudy, the seed or the soil is wet with the liquid. The process is exceedingly simple and inexpensive. Many packages of the inoculated material were sent out by the Department of Agriculture and the results of the work are reported in Bulletin No. 71 of the Bureau of Plant Industry, issued January 23, 1905. Subsequent studies have shown that cotton cultures as thus far developed are unreliable, and we are yet waiting for the perfection of the method. Unfortunately, all new developments, particularly those that have novel and striking features, are likely to be over-valued and sensationalized by undiscriminating persons, and this often results in injury to some of the best innovations. It is now to be determined what the possibilities of the new method are, under what exact conditions it may be expected to be successful, and how to eliminate the causes of failure. The biology of the organisms is not yet thoroughly understood. There is no indication that this new method of soil inoculation will be revolutionary, but there is every reason to think that it will carry us one step further toward the realization of our quest for nitrogen to provide food for mankind.

FERTILIZERS: THEIR KINDS AND CHARACTERISTICS

By *W. H. Jordan*

A fertilizer may be broadly defined to be any material which, when it is added to the soil, promotes the growth of plants. In a more restricted sense the term is applied to certain commercial substances or mixtures which contain one or more compounds that are regarded as having an especial relation to soil fertility.

In describing the relation of fertilizers to crop production, the fundamental considerations are, what are the essential constituents of plants, and what are the sources and supply of these constituents. The elements invariably found in normal agricultural plants include carbon, oxygen, hydrogen, nitrogen, phosphorus, sulfur, silicon, chlorin, potassium, sodium, calcium, magnesium and iron. Aluminum is constantly present in some species of plants, and manganese is occasionally a constituent of plant ash. Other elements are sometimes found, their presence in the plant being due to special conditions under which it is grown.

The elements which are known to be essential to vegetable growth include practically all of those that are normally present in agricultural plants. Carbon, oxygen, hydrogen and nitrogen are obviously necessary to the construction of the carbon compounds which form the main tissues of all vegetation. The same can be said of phosphorus and sulfur because of their relation to certain nitrogenous plant compounds. Experiments with water-cultures and with artificial soils have shown that phosphorus, sulfur, potassium, calcium, magnesium and iron, in a greater or less quantity, are indispensable to the normal development of agricultural plants, either because they enter into the structure of plant compounds or perform functions essential to growth. While chlorin, silicon and sodium are always present in plants, and in greatly variable quantities, scientific research has been unable to prove definitely the essentialness of these elements, at least in more than very minute proportions. The quantities of the essential elements of growth which various crops take up, especially nitrogen, phosphoric acid and potash, are now stated in tables, the figures of which are the averages of a large number of analyses. The following table gives these quantities for some of the more prominent crops:

POUNDS OF NITROGEN, PHOSPHORIC ACID AND POTASH IN 100 POUNDS OF VARIOUS CROPS

	Nitrogen	Phosphoric acid	Potash
Corn fodder (green)	.41	.15	.33
Corn fodder (dry)	1.76	.54	.89
Corn stover	1.04	.29	1.40
Red-top (dry)	1.15	.36	1.02
Timothy (dry)	1.26	.53	.90
Red clover (dry)	2.07	.38	2.20
Alfalfa (dry)	2.19	.51	1.68
Barley straw	1.31	.30	2.09
Wheat straw	.59	.12	.51
Oat straw	.62	.20	1.24
Potato tubers	.21	.07	.29
Sugar-beets	.22	.10	.48
Mangel-wurzels	.19	.09	.38
Corn kernels	1.82	.70	.40
Barley (grain)	1.51	.79	.48
Oats (grain)	2.06	.82	.62
Winter wheat (grain)	2.36	.89	.61
Rye (grain)	1.78	.82	.54
Buckwheat (grain)	1.44	.44	.21

The above figures should be taken only as indicating what is actually contained in agricultural plants on the average, and not as showing the amounts necessary to the production of a given crop. It is well known that some of the important mineral ingredients of the plant, especially the alkaline bases, are present in greatly variable proportions, due chiefly, we may believe, to the chemical environment of the plant roots. It has been demonstrated, for example, that plants may contain much more potash than is necessary to maximum growth. The minimum quantities of the constituents of the plant ash, which are essential to a given production of plant substance, are not yet determined. It is probable, however, that in the case of some of these constituents the quantities found in plants are considerably above what they actually need for their maximum development.

The immediate sources from which the plant draws its food are the soil and air. Carbon is supplied wholly from the carbon dioxid of the air, this being the only atmospheric element which under all conditions serves the plant as food without first being conveyed to the soil. The amount of carbon drawn from the air by a growing crop amounts to a thousand or more pounds per acre, in some cases, and were the supply of carbon dioxid not constantly replenished, it would in time become exhausted. As a matter of fact, all forms of rapid and slow combustion which involve the oxidation of organic matter, are continually renewing the atmospheric supply of carbon, and the observations so far made indicate that the proportion of carbon dioxid in the atmosphere remains practically unchanged. All the elements, excepting carbon and nitrogen, are derived wholly from the compounds of the soil (including water). Nitrogen is believed to be drawn entirely from the compounds of the soil for all crops but the legumes, which plants, under certain conditions, are able to appropriate their nitrogen from the atmosphere, wholly or in part. Just what proportion of the nitrogen in a legume crop is taken in ordinary farm practice from the air and not from the soil compounds has not been determined. The proportion undoubtedly varies with conditions. That the nitrogen in a clover or other legume crop, when such a crop is returned to the soil, is wholly an addition to the soil resources, is an inference not warranted by existing knowledge.

When we come to consider the soil we find that there are several sources of loss and gain of plant-food.

Sources of loss.

(1) *The production of crops.*—As already stated, the constituents of plants, with the exception of

carbon and more or less nitrogen in the case of the legumes, are drawn entirely from the soil. The available soil supply, therefore, is depleted by the amount of such constituents which are removed in the crop. In a system of farming that involves the sale of the crops as such and without their conversion into some animal product, the amount and composition of the crops measure the loss of plant-food to the farmer. When, however, crops are fed to animals and the resulting manures are applied to the soil, only a minor part of the commercially valuable materials used for plant growth are actually lost from the farm, the proportion being least when butter is the only product sold, and is determined in the production of meat by the quantities of constituents that are contained in the bodies of the animals.

(2) *Loss by drainage.*—When the amount of rain-water is in excess of the amount which the soil will hold plus that which is given back to the air through evaporation and transpiration by plants, drainage occurs. Drainage-water always contains more or less of the compounds that serve as plant-food. The most important of these is nitrogen in the form of nitrates. In determinations made by Lawes and Gilbert, the quantity of nitrogen as nitrates annually removed in drainage-waters varied from 31.8 to 57.9 pounds per acre. This loss is greatest in years of excessive rainfall and is larger from uncropped than from cropped land. The loss is increased by heavy applications of nitrogenous manures, especially of nitrates and ammonia salts. The proportions of phosphoric acid and potash in drainage-water are very small indeed, the loss in this way being unimportant.

(3) *Loss from fermentations.*—It has been clearly shown that under certain conditions, especially when the soil contains large amounts of organic matter without proper aëration, fermentations may occur which cause the loss of nitrogen from the soil in the free form. The extent to which such loss occurs under ordinary conditions has never been quantitatively estimated.

(4) *Loss from improper handling of farm manures.*—Large loss may be sustained by any given farm if the crops it produces are fed to animals and the resulting manure suffers leaching by water or is allowed to undergo such rapid fermentations as to cause the escape of free nitrogen or of its volatile compounds. Experiments with manure heaps located under unfavorable conditions have shown losses of at least one-half of the manurial value.

Sources of gain.

(1) *Fertilizers.*—The application of all farm manures and of all substances and mixtures usually classed as fertilizers, adds to the supply of the soil compounds which serve as plant-food, the quantity of such additions depending on the composition and amount of fertilizing materials used.

(2) *Rainfall.*—The precipitation of water, whether as rain or dew, brings to the soil certain compounds which are washed out of the atmosphere, the most important of these from the standpoint of plant growth being nitric acid and ammonia. Observations made at Rothamsted in the years 1853 to 1856 show that the amount of nitrogen thus conveyed to the soil varied from 5.9 to 8 pounds per acre. Other observers have found the quantity to be as high as 11 pounds per acre.

(3) *Fixation of nitrogen through the action of minute forms of vegetable life.*—It has been shown beyond question that certain forms of bacteria whose life is associated with leguminous plants, have the power of enabling the host plant to acquire atmospheric nitrogen. To the extent that the substance of these plants remains in the soil and decays, this action increases the supply of soil nitrogen. Other observations indicate that the same or other forms of bacteria cause the fixation of nitrogen directly in the soil. So far, no measurements have been taken of the extent to which soil bacteria cause an increase of the supply of soil nitrogen under the ordinary conditions of farm practice.

(4) *Supply of plant-food from the deep layers of the soil.*—The movements of soil-water cause more or less transference of soil compounds from one layer of soil to another. This movement is sometimes upward and sometimes downward. During that part of the year when the rainfall is scanty and the movement of the soil-water is almost entirely to the surface, there is unquestionably a transference of some soluble matters from the deeper to the upper layers of the soil. In view of the fact that this occurs generally during the season when crops are making active growth, this is a matter of considerable importance. It is not possible to know, of course, the extent to which the upper layers of the soil, in which the roots of the plant are most active, have their plant-food supply reinforced from the deeper layers.

(5) *Purchase of feeding stuffs.*—All feeding stuffs contain larger or smaller quantities of the elements essential to vegetable growth. Their purchase and use on the farm adds to the local supply of available plant-food.

The balance of plant-food supply and the availability of the food.

It is evident from the foregoing that there are constantly going on, through various causes, losses and gains of the supply of available compounds which serve as food for plants. To what extent the store of plant-food is being diminished or increased in general or particular localities, it is not possible to estimate. Nitrogen is continually in circulation from the air to the soil, from the soil to the plant, to drainage-waters and to the air, and from the plant and air back again to the soil. But just what proportion of loss or gain occurs of the forms of nitrogen that are available to the plant, it is impossible to state. Any definite figures on this point must be regarded as largely speculative.

When we consider the constituents of the soil we find that they exist in great store. Recent analyses at the New York Agricultural Experiment Station of samples of soils taken from nine localities in the state of New York, show that the soils which these samples represent contain on one acre to the depth of one foot, 1,900 to 7,260 pounds of nitrogen, 2,400 to 4,800 pounds of phosphoric acid, and 5,400 to 57,500 pounds of potash, this calculation being made on the assumption that the air-dry soil on one acre to the depth of one foot would weigh three million pounds. It is evident that these quantities represent, if entirely utilized, what would be sufficient for the production of crops during a long series of years. We are not in a position to know, however, the rate at which these quantities of compounds in the upper layers of soil are diminished, if diminished at all, under the usual systems of farm management. It is certainly true that large areas of land when managed in accordance with what are regarded as correct practices, have continued to grow undiminished and luxuriant crops during a long series of years.

Available plant-food is that which is in such forms and is so located that it can be appropriated by growing plants. Only a very small proportion of the total phosphorus, potassium, calcium and other elements present in a soil is available to plant uses at any given time. A recent treatment at the New York Agricultural Experiment Station of nine soils by leaching for ten days with a very weak acid, 1-200 normal strength, removed on the average only one part in seventy-four of the total potash and one part in one hundred and forty-four of the total phosphoric acid. Leaching with water for the same length of time extracted one part in two hundred and thirty-two of the potash and one part in one hundred and forty-two of the phosphoric acid. The first method of treatment probably disclosed the maximum availability. It is entirely rational to characterize these easily soluble compounds, when used by plants, as that plant-food which is in circulation. It passes from the soil to the plant and from the plant back to the soil through various stages and avenues, and it is during certain of these transferences that loss, as far as availability is concerned, is sustained. It is the circulatory plant-food that is the farmer's most valuable factor in his business, and its conservation should be scrupulously guarded.

It should be remembered in this discussion that availability in its application to the feeding of the various farm crops is a relative term. A soil may return large yields of one crop and, under similar conditions, small yields of another. Certain observations indicate that this fact is to be explained by what may be termed the unlike feeding power of different species. Experiments conducted with various forms of phosphoric acid, some rendered soluble and others being in the condition of the original phosphatic rock, all other conditions in the artificial soils being similar, show that the members of one family of plants are able to obtain phosphoric acid from combinations which are unavailable to the species belonging to another family. That similar influences prevail in the production of field crops can scarcely be doubted. It is reasonable to suppose, also, that apart from the matter of solubility, some combinations of plant-food ingredients form a more sympathetic root environment for a particular species than do other forms, and, for this reason, availability for a particular species may be determined by the kind rather than the amount of soil compounds.

In discussing the nature of the influence of commercial fertilizers on the crop-producing power of the soil, it is essential to define, as far as this may be done, what fertility is. The conditions which determine soil fertility are complex. They involve, in a general way, the following:

(1) A supply of available plant-building material sufficient in quantity and adapted in kind to the plant under cultivation.

(2) Soil texture favorable both to the transpiration and conservation of soil moisture, and such heat conditions as are required by the particular crop grown.

(3) The maintenance of a soil environment favorable to the necessary biological activities.

The supply of available plant-food.

It is clear that there are minimum quantities of most of the constituents of plants which are absolutely essential to normal and perfected growth. An inadequate supply of any one of these constituents restricts growth. It has come to be generally accepted, at least in practice, that when such deficiencies occur it is generally with the compounds of one or more of three elements,—nitrogen, phosphorus and potassium. Experience in the application of the compounds of these elements to the soil, the fact that such compounds exist in the soil in very small proportions, and the prominence of their relations to the economy of the plant, are all facts which go far toward sustaining this point of view. It should be remembered, however, that most commercial fertilizers carry not only compounds of nitrogen, phosphoric acid and potash, but also salts of lime and magnesia, and it does not appear to be clearly demonstrated because of the effect of such mixtures, that the benefits of fertilizers always pertain to the three elements which are regarded as most important; viz: nitrogen, phosphorus and potassium.

While large increases of crops from the application of commercial fertilizers are conceded to occur, the usual explanation of this result is now seriously questioned by some investigators. The view which has been most prevalent, in practice at least, regards fertility as a mathematical problem; that is, the mere matter of loss and gain of soil constituents. More specifically stated, a farmer would be regarded as maintaining his soil fertility if he returns to his land as much as the crops take out, or more. Recently, however, through the publications of the United States Department of Agriculture, and from other sources, the importance of soil conditions as compared with soil composition has been urged to the extent of largely ignoring the earlier point of view. The profitable effect of commercial fertilizers is admitted, but this effect is believed by some investigators to be due to a modification of soil conditions which lie outside of mere quantitative relations.

Most commercial fertilizers contain soluble salts of nitrogen, phosphoric acid and potash, or if not soluble salts of nitrogen, organic materials which undergo rapid decomposition with the formation of inorganic salts. The introduction of such compounds into the soil may produce an effect in several directions. In the first place, there is an increased amount of that store of material which is rapidly available as plant-food. In the second place, what may be called the chemical status of the soil is changed. It is a well-established fact that when soluble salts are introduced into the soil, a double decomposition takes place with an exchange of acids between the bases introduced and those already present. For instance, if a solution of potassium nitrate is turned on a column of soil, contained in a tall glass vessel, the nitric acid will appear in the drainage water in combination with some other bases, chiefly lime, until an excess of the solution has been used. Similar changes occur with other salts. It is obvious that such transformations may very materially modify soil solutions and change what may be termed the chemical environment of the plant roots, which change may be favorable or unfavorable to a particular plant. But while soil conditions, which may be greatly modified by cultivation and manuring, are a large factor in fertility, data are not yet at hand which justify an abandonment of the prevailing views as to the enrichment of the soil through the use of fertilizers. While plants may be unable to feed because of untoward soil or atmospheric conditions, it is entirely reasonable to believe that circumstances may and do exist when, even with the most favorable physical and chemical status of the soil, accompanied by a sufficient supply of soil moisture, the supply of available plant-food would not sustain the growth of a maximum crop. Common observation, as well as scientific data, indicate that this supply is often a controlling factor in crop production. The fact that commercial fertilizers are shown to sustain soil fertility through a long series of years; the clustering of roots around bone or other vegetable or animal substances and the consequent prosperity of the plant; the long-continued effect of heavy applications to very limited areas of soil, as for instance, the uneven effect on grass of manuring some hoed crop on the hill; the unquestioned influence, as shown by experimental evidence, of relatively insoluble forms of phosphoric acid on plant growth, it being scarcely possible that small quantities of these comparatively inert materials could to any extent modify the chemical or physical status of the soil; and the comparatively small influence usually resulting from chemical manuring unless compounds are present containing one or more of the elements, nitrogen, phosphorus and potassium; all these facts are scarcely explained wholly on the basis of modifying soil conditions. But, whatever the explanation, the main result is the same, that is, the plant is able to acquire and assimilate a larger amount of raw materials because of the introduction of the fertilizers into the soil, and the economic importance of this result to the farmer is independent of the operating causes.

Favorable soil conditions.

It is conceivable that heavy applications of fertilizers may materially modify soil texture. This would be especially true of liming. In general, however, physical conditions are mainly due to original soil formations, to the system of cropping and to methods of tillage.

Equally important with many other factors are the activities maintained by various bacterial forms of life. [Chapter XIII.] It is well known that the nitrogen added to the soil in organic forms must be changed to combinations of nitric acid before it can serve the plant, and that this change is brought about through the action of bacteria. As previously stated, bacteria are important in the acquisition of nitrogen by certain legumes, and possibly in the direct acquisition by the soil of atmospheric nitrogen. It is obvious that the soil environment should be favorable to the presence and activity of this germ life. That this environment may be modified by fertilizers, either favorably or unfavorably, is evident when we recall that the prosperity of certain bacteria is dependent on the reaction of the medium in which they are growing. It is well established that neutral or slightly alkaline media are more favorable for the development of the legume bacteria than is an acid reaction. It also appears that an abundance of nitrogenous compounds in the soil exerts an unfavorable influence on the activity of this form of germ life.

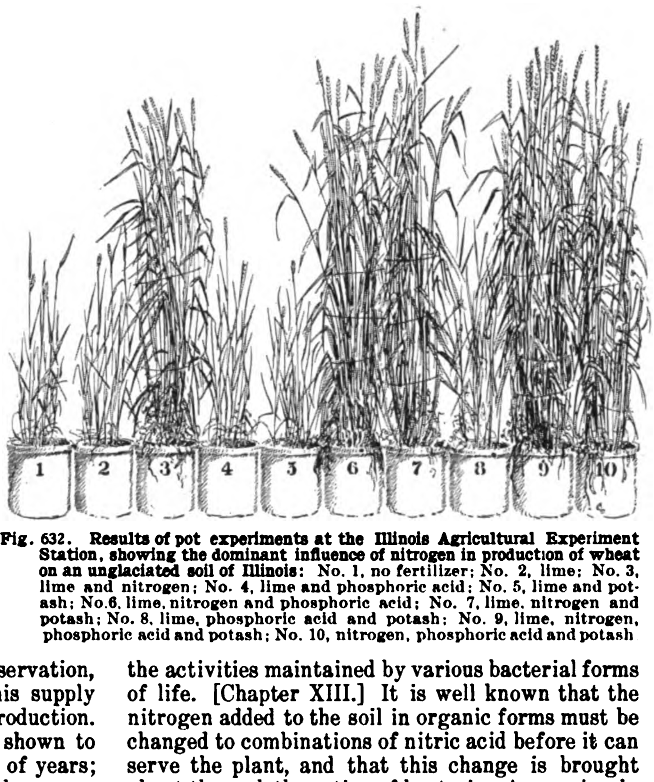


Fig. 632. Results of pot experiments at the Illinois Agricultural Experiment Station, showing the dominant influence of nitrogen in production of wheat on an unglaciated soil of Illinois: No. 1, no fertilizer; No. 2, lime; No. 3, lime and nitrogen; No. 4, lime and phosphoric acid; No. 5, lime and potash; No. 6, lime, nitrogen and phosphoric acid; No. 7, lime, nitrogen and potash; No. 8, lime, phosphoric acid and potash; No. 9, lime, nitrogen, phosphoric acid and potash; No. 10, nitrogen, phosphoric acid and potash

The commercial articles that are used for promoting soil fertility include chemicals and raw materials which bear names descriptive of their character, and manufactured articles or mixed fertilizers that are the result of compounding chemicals and raw materials in various proportions, and which, as a rule, bear proprietary names. Chemicals and raw materials are usually classified into nitrogenous, phosphatic and potash fertilizers, that is, according as these materials furnish chiefly nitrogen, phosphoric acid or potash.

Nitrogenous fertilizers.

Nitrogen-bearing fertilizers consist either of certain salts, such as the nitrates of sodium and potassium, or of animal and vegetable by-products, such as dried blood, tankage and cottonseed meal. We may first consider the nitrogen-bearing chemicals (first four paragraphs) and then the organic ammoniates. Pictorial results in the use of nitrogenous fertilizers are shown in Figs. 632, 633.

Fig. 633. Result of experiments at the Rhode Island Agricultural Experiment Station, showing effects of nitrogen on the production of hay (timothy with some red-top). Cock at left received no nitrogen; cock in center, one-third ration of nitrogen (21 pounds per acre); cock at right, full ration of nitrogen (63 pounds per acre). All three plots manured alike with acid phosphate and muriate of potash.

Sodium nitrate, otherwise known as nitrate of soda, Chile saltpeter and cubic niter, contains in its pure form 16.3 per cent of nitrogen. It is obtained almost entirely from niter beds found in the countries lying along the western coast of South America, principally in Chile. These beds, which average about three feet in thickness, extend over large areas and contain about 50 per cent of sodium nitrate. The sodium nitrate is purified by crystallizing it out of solutions of the crude niter. The purified product varies from 95 to 98 per cent of sodium nitrate and carries on the average about 15.6 per cent of nitrogen. The world's consumption of this material for the year 1903 was 1,429,150 tons, of which 264,000 tons came to the United States.

Nitrate of potash.—This is to some extent a natural product, but at present it is chiefly manufactured from sodium nitrate. The pure salt contains 13.8 per cent of nitrogen and the commercial product between 12 and 13 per cent. It has been used chiefly in the past for the manufacture of explosives and has borne such a price that it has not been available for agricultural use. The price is now such that in consideration of the fact that this compound carries potash, as well as nitrogen, it may be economically purchased as a combined source of nitrogen and potash.

Nitrogen as a nitrate is the most immediately available form in which to supply this element to plants. Because the nitrates are easily leached from the soil during an excess of rainfall, they should not be applied to crops until they are needed, and only in such quantities as are necessary for immediate use. The above statements concerning the use of nitrates apply to nitrate of potash as far as the nitrogen is concerned, but similar precautions are not necessary with reference to the loss of potash.

Sulfate of ammonia.—Ammonium sulfate is a by-product from coke-making and from various chemical industries. The output in the United States for the year 1900 was 24,977,185 pounds. Of this, about one-third was used by the fertilizer industry. This material should contain 19 to 21 per cent of nitrogen. It is the most concentrated form in which nitrogen can be applied to the soil, but its use as such, or as a source of nitrogen for mixed fertilizers, has been somewhat limited by the larger cost of nitrogen in this combination. It is held that the nitrogen of this compound is changed in the soil to the nitric form before becoming available for plants.

Dried blood.—Blood from the slaughter of live-stock is collected in tanks and boiled to coagulate the albuminoids present. The water is then pressed out and the resulting pressed cake is broken up and dried. This, after grinding, is put on the market as dried blood, on a 14 per cent nitrogen basis. A lower grade, mixed with tankage and other materials, sometimes sold as red blood, contains 10 to 12 per cent of nitrogen.

Concentrated tankage. (*"Sticks."*)—The liquor resulting from the cooking and cleaning of bones and steaming tankage, which contains considerable nitrogenous matter, is evaporated to a sticky substance that carries a high percentage of nitrogen. This material, even if rendered thoroughly dry, cannot be handled as such because it rapidly takes up moisture and liquefies. To overcome this difficulty, "stick" is mixed with a chemical containing sulfates of iron and aluminum. The mixture can then be kept indefinitely. This product carries 12 to 13 per cent of nitrogen.

Tankage.—This product is a combination of various wastes from slaughter-houses, including intestines, lungs, tendons, bones, blood and other refuse nitrogenous matter. It is cooked in tanks under steam pressure to extract the fat, and the residue is pressed to remove surplus water. The resulting material, carrying about 50 per cent of moisture, is then dried and ground and may be used in the manufacture of mixed fertilizers or may be sold as such for direct use. The proportion of nitrogen in this product varies considerably, depending on the percentage of bone present, but will range from 5 to 10 per cent.

Hoof meal.—The imperfect hoofs that are unfit for the manufacture of buttons and various novelties, are thoroughly steamed under pressure and are then kiln-dried and ground into a fine condition. The proportion of nitrogen in this material is from 15 to 16 per cent.

Raw and steamed bone.—These by-products are sources of nitrogen, although they are more important as sources of phosphoric acid. Raw bone contains 4 to 5 per cent of nitrogen and steamed bone 1 to 3 per cent. These materials will be more fully described under the head of phosphatic fertilizers.

Dried and ground fish.—This product is manufactured out of the refuse of fish packing and canning houses, or from the fish pomace from which oil has been extracted. The refuse from the manufacture of fish-oil furnishes the most uniform product and contains, on the average, 7 to 8 per cent of nitrogen and 6 to 8 per cent of phosphoric acid. The scraps from the packing and canning houses vary greatly in composition according to the proportions of bone, skin and flesh. These by-products, before appearing in the market, are dried and ground, although they find a limited use in the fresh or crude condition by those who live near the immediate sources of supply.

Oil meals are a desirable source of nitrogen for crops. This is especially true of cottonseed meal, which carries approximately 7 per cent of nitrogen, accompanied by smaller percentages of phosphoric acid and potash.

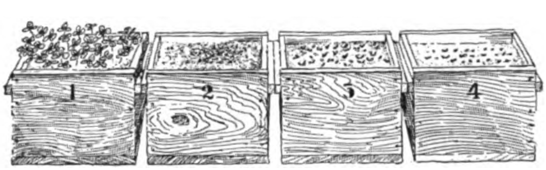


Fig. 635. Clover (immature). Experiment at Maine Experiment Station. Effect of different forms of phosphoric acid. No. 1, phosphoric acid soluble in water (acid phosphate); No. 2, phosphoric acid insoluble in water (finely ground undissolved S. C. rock); No 3, phosphoric acid insoluble in water (dehydrated phosphate of iron and aluminum); No. 4, no phosphoric acid. All needed elements were added to all boxes, except that no phosphoric acid was added to No.4.

Low grade materials.—There are certain animal waste products which, while they contain in some cases high percentages of nitrogen, are so inert or slow of decomposition in their natural form, that they have an inferior value. These include, among other substances, waste wool, waste hair, bristles, feathers, leather scrap and shoddy. While in their natural condition, these materials give up their nitrogen to plants very slowly indeed. It is asserted that when decomposed with sulfuric acid the resulting products have an agricultural value fairly comparable with other ammoniates. This conclusion needs experimental proof, however.

Raw phosphates.

Phosphoric acid is applied to the land only to a very limited extent in the forms and combinations in which it exists in nature. Fertilizers as they appear in the market contain this ingredient chiefly in combinations which have been produced by chemical treatment of the raw phosphates. Results with phosphatic fertilizers are shown in Figs. 634–639.

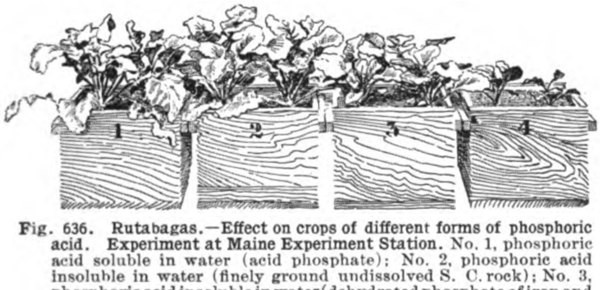


Fig. 636. Rutabagas.—Effect on crops of different forms of phosphoric acid. Experiment at Maine Experiment Station. No. 1, phosphoric acid soluble in water (acid phosphate); No. 2, phosphoric acid insoluble in water (finely ground undissolved S. C. rock); No. 3, phosphoric acid insoluble in water (dehydrated phosphate of iron and aluminum); No. 4, no phosphoric acid. All needed elements were added to all boxes, except that no phosphoric acid was added to No. 4.

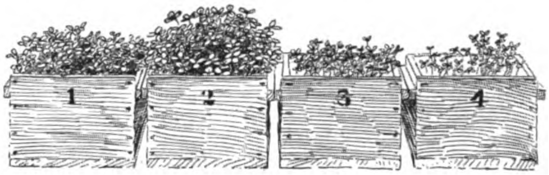


Fig. 634. Clover (mature).—Experiment at Maine Experiment Station. Effect of different forms of phosphoric acid. No. 1, phosphoric acid soluble in water (acid phosphate); No. 2, phosphoric acid insoluble in water (finely ground undissolved S. C. rock); No. 3, phosphoric acid insoluble in water (dehydrated phosphate of iron and aluminum); No. 4, no phosphoric acid.

Mineral phosphates.—The origin of a large proportion of the phosphatic rock is now traced to extinct forms of marine animal life. The phosphoric acid exists in such rock as tri-calcic phosphate mixed with various impurities, such as calcium and magnesium carbonates, iron and aluminum oxides, silicates, and sometimes other compounds. The chief deposits of phosphate rock in the United States are found in Florida, South Carolina and Tennessee. The output of this rock in the United States in 1902 was about 1,500,000 long tons, valued at approximately $5,000,000.

The deposits of phosphate rock in the southern states are classified into several varieties, according to their character and composition, those found in Florida being known as hard rock, land pebble and river pebble, and those found in South Carolina as river rock and land rock. In Tennessee the classification is according to color, into blue, brown and white. These varieties vary in composition from 25 to 35 per cent of phosphoric anhydrid. This rock, after mining, is washed, picked, dried in kilns, and is then ready to ship for market. It is sold to manufacturers on the basis of definite guarantees, which vary according to the source of the rock. The manufacturer grinds it, treats it with sulfuric acid, and from this source supplies the great bulk of available phosphoric acid compounds found in fertilizers.

There are in various parts of the world large deposits of mineral phosphates known as apatite. This material is less desirable for manufacturing purposes because of its hardness and because of the presence of chlorine and fluorine.

The West Indian Islands have in the past yielded considerable quantities of mineral phosphates which may be regarded as phosphatic guanos, that is, materials resulting from the washing out of the soluble nitrogenous matters of the excrement of sea birds and other forms of marine life. These guanos are rich in phosphoric acid, carrying 30 to 40 per cent. The deposits from certain islands make a high quality of superphosphate, others do not. The so-called Navassa phosphate, for instance, is not a good material for the preparation of superphosphate, as it contains a considerable quantity of compounds of iron and aluminum.

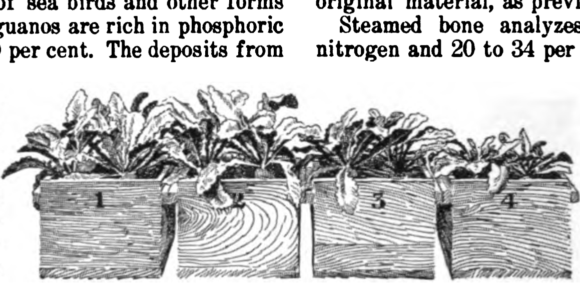


Fig. 637. Turnips.—Experiment at Maine Experiment Station. Effect of different forms of phosphoric acid. No. 1, phosphoric acid soluble in water (acid phosphate); No. 2, phosphoric acid insoluble in water (finely ground undissolved S. C. rock); No. 3, phosphoric acid insoluble in water (dehydrated phosphate of iron and aluminum); No. 4, no phosphoric acid. All needed elements added to all boxes, except that no phosphoric acid was added to No. 4.

Thomas slag.— This material, sometimes known as Thomas slag powder, basic slag, or basic cinder, is a by-product from the production of steel. In the manufacture of steel it is necessary to remove the phosphorus from the pig iron, which is done by the use of lime, the phosphorus becoming oxidized and uniting in the form of tetracalcium phosphate. The phosphoric acid in this by-product varies from 14 to 20 per cent, and is much more easily soluble than that in most other mineral phosphates. Experience also shows it to be more readily available to plants. This material has not found an extensive use in this country, but is largely used in Germany, where the total consumption as long ago as 1896 was estimated at 800,000 tons annually. Its use has been found to be especially favorable to turnips, but is, in general, better adapted to crops where an immediate intensive effect is not desired.

Bone.—The bones that are collected at abattoirs in the slaughter of cattle and hogs, appear in the market as raw bone and bone that has been cooked. The raw bone, which before grinding has been thrown into boiling water just long enough to loosen the adhering particles of meat and fat, contains a higher percentage of nitrogen and a smaller percentage of phosphoric acid than the steamed bone, the proportions being approximately 4 per cent of nitrogen and 22 per cent of phosphoric acid.

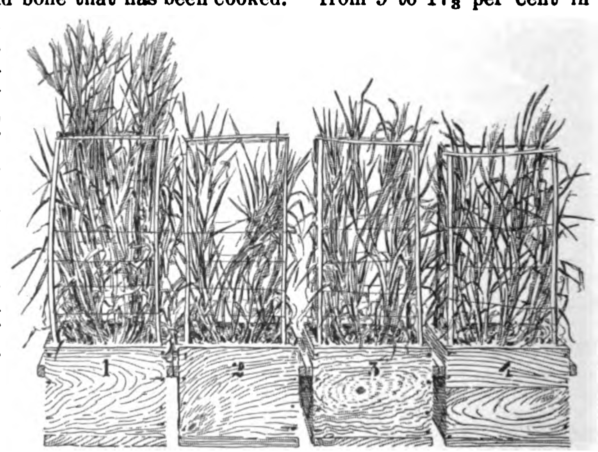


Fig. 638. Barley.—Experiment at Maine Experiment Station. Production of various crops as affected by different forms of phosphoric acid. No. 1, phosphoric acid soluble in water (acid phosphate); No. 2, phosphoric acid insoluble in water (finely ground undissolved S. C. rock); No. 3, phosphoric acid insoluble in water (dehydrated phosphate of iron and aluminum); No. 4, no phosphoric acid. All needed elements were added to all boxes, except that no phosphoric acid was added to No. 4.

A large proportion of the bone from slaughter - houses is cooked in tanks to remove the glue and fat. This takes out much of the nitrogenous organic matter, and the residue, of course, is poorer in nitrogen and richer in phosphoric acid than the original material, as previously stated.

Steamed bone analyzes 1 to 3 per cent of nitrogen and 20 to 34 per cent of phosphoric acid. Both forms of bone when not treated for the manufacturing of a superphosphate, appear in the market as bone-meal. The phosphoric acid present in the bone is in the form of tri-calcic phosphate and is associated principally with a smaller proportion of calcium carbonate.

Tankage.—This product is a source of phosphoric acid because of the bone which it contains in greatly varying proportions. The phosphoric acid in this material varies in a general way from 2.5 to 18 per cent and is present in the insoluble form.

Potash fertilizers.

The first, and a long-standing source of commercial potash, was wood-ashes. For many years, however, this waste product has proved entirely inadequate to supply the agricultural demand. The potash now used for crop production is almost entirely imported from Germany, where it is obtained from mines located at Stassfurt near the Harz mountains. The potash-bearing strata of these mines are found 1,200 to 2,500 feet beneath the earth's surface, and yield crude salts known as carnallit, kainit, sylvinit and Hartsalz, which are mixtures principally of chlorids and sulfates of potassium, sodium and magnesium, the percentage of actual potash varying from 9 to 17½ per cent in the different products. These crude salts are not imported into this country to any great extent as such, excepting kainit, which is used somewhat for agricultural purposes. Sylvinit was imported in considerable quantities at one time, but in 1904 the amount fell to 500 tons.

Through various processes of purification, salts are obtained which supply potash in much more concentrated forms than the natural products. A brief description of the principal ones follows. Fig. 640 shows a potash-fertilizer experiment.

Muriate of potash.—In this salt the potassium is in combination with chlorine, and the various grades contain 46.7 to 62 per cent of actual potash, according to the degree of purity. When sold for fertilizing purposes, the basis is 80 per cent of pure muriate of potash, corresponding to 50.5 per cent of actual potash. The price is increased or decreased according as the potash rises above or falls below this basis, This is the cheapest form of potash to the farmer and the one largely used in general farming. For certain crops it is objectionable because of its influence on their quality. This is especially true of tobacco.

Sulfate of potash. — This is a combination of potash and sulfuric acid, varying as it appears on the market from 90 to 96 per cent of pure sulfate, or from 46 to 52 per cent of actual potash. It is more expensive as a source of potash than the muriate, but it is preferred for the production of tobacco, oranges, sugar-cane and tender vegetables. It is not so extensively used as the muriate, but its use is increasing.

Sulfate of potash-magnesia.—This is chiefly a mixture of the sulfates of potassium and magnesium, and has been found to carry 25.9 to 27.2 per cent of actual potash. As to expensiveness and use, it stands in about the same position as the sulfate of potash.

Twenty per cent manure salt and 30 *per cent manure salt.*—In these products the potash is in the form of the muriate, being associated with large percentages of sodium chlorid or common salt. While supplying potash as cheaply per unit in the large markets as does the higher grade muriate, these salts are more expensive to the farmer, because of the greater cost for freighting a given quantity of actual potash.

Fig. 639. Results of experiment by Ohio Agricultural Experiment Station, showing the influence of acid phosphate alone on the growth of tobacco. No. 1, unfertilized; No. 2, received 480 pounds acid phosphate per acre.

Kainit.—As previously stated, this is a native potash-bearing mineral. The percentage of actual potash present is shown to vary from 12.4 to 12.8 per cent. It is a more expensive source of potash than the muriate because of larger freight cost, and there are no reasons why it should be preferred, although it is effective when mixed with stable manure as a means of preventing the loss of nitrogen.

Fig. 640. Result of experiment by the Illinois Experiment Station, showing influence of salt of potassium alone in increasing the yield of corn on peaty, swampy land. Plot on left received 200 pounds of steamed bone meal. Plot on right received 100 to 200 pounds potassium salt.

Wood-ashes.—Potash is present in wood-ashes as the carbonate, a desirable form for all agricultural uses. The proportion varies greatly according to the species of wood from which the ash is derived. In general, "soft" wood-ashes are poorer in potash than ashes from "hard" wood. Ashes collected from miscellaneous sources are likely to contain much foreign material and should be purchased only on a guarantee, which in the case of mixed domestic ashes should not be less than 5 per cent of actual potash. Wood-ashes contain a small percentage of insoluble phosphoric acid and a large proportion of lime. Their effect on the fertility of land is therefore not necessarily due wholly to the potash compounds present but may be the resultant of the action of a number of compounds including phosphates and carbonates of calcium and magnesium.

Manufactured fertilizers.

Compared with the total consumption of fertilizers, chemicals and raw materials are used in relatively small quantities. The great bulk of commercial plant-food is placed on the market in the form of mixed goods, that is, mixtures that have been compounded by the use of chemicals and raw materials in such proportions as to secure any desired percentages of nitrogen, phosphoric acid and potash.

Acid phosphates.—The fundamental operation in the manufacture of so-called superphosphates, subsequent to the grinding of the bone or rock, is the treatment of the raw phosphate with sulfuric acid (oil of vitriol), the object of this treatment being to bring the phosphoric acid into such combinations, that on its application to the soil it is immediately available to the plant. When normal calcic phosphate, sulfuric acid and water are mixed together in the proper proportions, chemical reactions occur with the formation principally of mono-calcic phosphate, a compound soluble in water, and hydrated calcium sulfate. By varying the strength and proportions of the sulfuric acid, free phosphoric acid may be produced or di-calcic phosphate, the latter a compound insoluble in water, but which is regarded as readily available to plants.

The usual reaction that is secured is as follows:

$$Ca_3(Po_4)_2 + 2H_2SO_4 + 2H_2O = CaH_4(PO_4)_2 \times 2CaSO_4 + 2H_2O.$$

The proportion of sulfuric acid that it is necessary to use with any given material is based principally on the percentage of phosphoric acid present as normal calcium phosphate. It is necessary to allow also for other compounds present which use up the sulfuric acid, especially calcium carbonate, the reaction with which is the following:

$$CaCo_3 + H_2SO_4 = CaSO_4 + H_2O + CO_2.$$

The strength of sulfuric acid best adapted to the manufacture of acid phosphate is found to be one with a specific gravity approximately of 1.55. Carboy acid has a specific gravity of 1.82 and must be diluted with water before using, the quantities to be used in order to secure a diluted acid with a specific gravity of 1.55 being in the proportion of 1,000 pounds of acid to 400 pounds of water, or, by volume, 11 parts of acid to 8 parts of water.

The quantity of diluted acid, of a specific gravity of 1.55, required to produce the mono-calcic phosphate, is 215 parts for each 100 parts of phosphoric anhydrid (P_2O_5), and the quantity of acid required for each 100 parts of lime that is in excess of the lime combined with the phosphoric acid, is 273 parts. If, therefore, a mineral phosphate contains 25 per cent of phosphoric anhydrid and 10 per cent of excess of lime, the 500 pounds of phosphoric anhydrid in one ton would require 1,075 pounds of the diluted acid to convert it to the form of mono-calcic phosphate, and the 200 pounds of the excess of lime in one ton would require 546 pounds of the diluted acid in order to convert it into the calcium sulfate, in all, 1,620 pounds of acid, specific gravity 1.55, with one ton of the raw phosphate. It is probably wise to use a small excess above the theoretical quantity, because of the presence in the mineral phosphate of compounds other than those taken into consideration. In case the users of superphosphates undertake to manufacture their own materials from the raw mineral phosphate, which is seldom wise unless the quantity to be used is rather large, the following brief directions may be found useful: The treatment of raw phosphate should take place in iron or wooden receptacles or else in those lined with lead. In diluting the strong acid it should be turned into the water, rather than the reverse process. Great care should be taken in handling the acid, because it causes severe burns when in contact with the flesh at its full strength. The raw phosphate, which must be very finely ground, is then very gradually stirred into the acid until a thorough mixture is secured. This mixture should be allowed to stand for several days and then may be compounded with nitrogenous and potash materials in case it is desired to produce a mixed fertilizer. As a rule, however, it is wiser for consumers who are using superphosphates in moderate quantities to purchase acid phosphate rather than to attempt to manufacture it.

The mechanical condition of acid phosphates is most satisfactory when manufactured from mineral phosphates. With bone alone it is difficult to secure a dry product, and it is wise to use in part a mineral phosphate or else it becomes necessary to mix the dissolved bone with a drier. Sometimes certain nitrogenous materials, on which it is desirable to secure the disintegrating effect of the sulfuric acid, are mixed with the ground phosphate before applying the sulfuric acid. With such substances as hoof, horn, shoddy and hair, this method undoubtedly increases the availability of the nitrogen present.

Mixed fertilizers.—The mixed fertilizers, which constitute the great bulk of commercial fertilizing material, are as a rule compounded by using acid phosphate as a basis and mixing with it nitrogenous and potash substances in such proportions as to produce any desired composition. To illustrate, if with 1,000 pounds acid phosphate containing 14 per cent available phosphoric acid, there is mixed 200 pounds of muriate of potash, 50 per cent actual potash, 600 pounds of dried blood, 10 per cent nitrogen, and 200 pounds nitrate of soda, 15½ per cent nitrogen, the whole constituting one ton, there is secured a mixture carrying approximately 4½ per cent of nitrogen, 7 per cent available phosphoric acid and 5 per cent of potash; or, if with 1,400 pounds of acid phosphate, 14 per cent available phosphoric acid, there is mixed 100 pounds of muriate of potash, 50 per cent actual potash, 400 pounds of dried blood, 10 per cent nitrogen, and 100 pounds nitrate of soda, 15½ per cent nitrogen, there would be a mixture carrying approximately 2.7 per cent nitrogen, 9.8 per cent available phosphoric acid and 2.5 per cent of potash. By varying the proportions of chemicals and raw materials, it is possible to secure mixtures of the valuable ingredients in great variety. As a matter of fact, the mixed fertilizers in the market contain nitrogen, phosphoric acid and potash in almost every possible proportion. It would be gratifying in this connection to be able to state that the manufacturers of fertilizers are compounding their goods in accordance with well-defined principles as applying either to particular soils or particular crops. It is evident that this is not done, if indeed it is either possible or rational. Certainly the mixed fertilizers offered for sale do not contain the important ingredients in the proportions required by plants, even in case of those mixtures supposed to be especially adapted to particular crops. As a rule, the phosphoric acid in fertilizers exceeds greatly the proportions found in the plant as compared with the nitrogen and potash, a condition which is doubtless dictated by the results of practice. To use the composition of the crop as a basis for compounding fertilizers is to ignore other dominant factors such as the needs of the soil and the system of farming. Such a practice would be not only irrational but expensive.

To be sure, some mixtures of fertilizers are compounded with reference to well-known facts. For example, the potash in tobacco manures is always supplied in some form other than the muriate, because of the deleterious influence of this compound on the quality of the tobacco leaf. It is regarded as essential that fertilizers compounded for the top-dressing of grass lands shall contain their ingredients in the most soluble forms. There is convincing evidence that for the production of grain crops, especially wheat, a more generous proportion of nitrogen should be supplied than is necessary for other crops, and we now know that in fertilizing legumes, it is wise to apply no nitrogen, or only a minimum proportion. But aside from these and a few other definite principles, it cannot be said that the composition of special manures that are now in the market represents anything that is of practical value to crop producers. In any given locality, corn manures, so called, are as likely to be efficient on potatoes as on corn, and many so-called potato manures might, under certain conditions, be rationally used on wheat. It is time for the public to disabuse its mind of the idea that the nomenclature of the fertilizer trade means very much.

Moreover, it is proper to state that the claims of manufacturers for the superiority of their goods, either through special processes of manufacture or special classes of material, are to be regarded with suspicion. The quality of the manufactured product depends, in part, on the efficiency of the machinery, and no manufacturing concern controls machinery better than is available to all manufacturers. The best grades of raw materials and chemicals are in the open market and are not monopolized by any locality or by particular manufacturers. When a fertilizer contains materials of a high grade, is dry and in a good mechanical condition, it possesses all possible good qualities. It is true that a manufacturer may use inferior materials in such a way as very largely to escape detection, but this is apart from the possibilities that lie within the reach of every manufacturer.

Considerations determining the purchase and use of fertilizers.

It is undoubtedly true that the majority of the consumers of fertilizers buy these materials without a definite knowledge as to whether the mixtures purchased are the most efficient and economical to apply to their farms. Without question, however, the use of commercial plant-food rests on local considerations, and it is incumbent on each farmer to determine under the conditions of his farm practice what mixtures it is wisest for him to purchase. The considerations affecting this question are several:

The character of the soil.—Soils are greatly unlike in origin and consequently in composition. It is obvious, therefore, that they furnish to plants materials for growth unlike in character and proportion. This being true, we would naturally look for different fertilizer requirements. As a matter of fact, observation teaches that a given fertilizer mixture produces quite unlike effects in different localities, effects which are of course more or less modified by season. It remains, therefore, for the individual farmer to determine by experimental evidence what ingredient or ingredients, and in what proportions, secure for him an increase in crop production at the least cost. Unquestionably the soil is the main factor in determining the kind and form of plant-food which it is wise to purchase.

Kind of crop grown.—If an attempt were made to produce a crop on a blank soil, that is, one containing no plant-food whatever, it would be necessary and economical to supply to that soil the various ingredients of plant-growth in an available form in the proportions used by the crop in hand. It is not logical, however, to apply this principle to crop production, because soils are not blank and in some cases, at least, furnish without fertilization all of one or more of the commercially valuable ingredients that the plant needs. It is true that after the continued use for a long time of what are called incomplete fertilizers, a deficiency of one or more needed soil compounds may develop. When this condition is reached it is time to give it practical recognition. It is not good business policy to anticipate a possible soil deficit when it involves purchasing for many years a supply of materials that is not actually needed. However, when conditions are unknown and the safe production of a valuable crop is at stake, the application of a complete fertilizer may be the wisest course to pursue, though perhaps not the most economical. Nevertheless, it is conceivable that a plant requiring generous quantities of potash might fail of maximum production where another crop appropriating less potash would attain its greatest thrift. For this reason it is wise to take into consideration the composition of the plant, especially when the same crop is produced on the same soil during a long series of years. In forcing-house crop production, the composition of the crops may rationally constitute a chief factor in the compounding of the fertilizers, because under these conditions the production is intensive and of high-priced materials, and on soils that are more or less artificial in character. The forms in which the fertilizing ingredients should be applied and the times of application may properly be determined, in some cases at least, by the kind of crop.

The system of farm management, or the business to which the farm is devoted.—Two greatly unlike systems of farming are the production of crops to be sold as such, and the application of these crops to animal husbandry, especially to dairying. The latter system of farming is generally accompanied by the generous purchase of feeding stuffs carrying, in the aggregate, large quantities of available plant-food. Moreover, the materials withdrawn from the soil by the crops are largely returned to the land through the animal excreta. When the crops are sold as such, all the materials drawn from the soil are transported from the farm. Nothing is plainer, then, than that the utilization of the crops on the farm, accompanied by the purchase of nitrogenous cattle foods and the application to the land of the resulting rich manure, would very materially modify the kind and quantity of plant-food which it would be necessary to purchase as compared with a system of farming which invoves the sale of crops as a source of income. This point might be further illustrated by citing the case of the market-gardener with whom earliness and rapidity of growth are important considerations, wisely leading him to use fertilizers generously and of such a character as to meet immediately and fully all possible needs of the plant. The point of view of such a producer is quite different from that of the general farmer.

Relative values of ingredients.

This subject can be considered from two points of view,—the commercial value of fertilizing ingredients and the agricultural value. In a given instance there is not, necessarily, any relation between the two kinds of values. The commercial value of any ingredient in a given form is determined by the market price of the material bearing it. For instance, if nitrate of soda carrying 15 per cent of nitrogen costs $45 per ton, a pound of nitrogen in this substance would cost the consumer 15 cents; or, again, if a ton of acid phosphate containing 14 per cent of available phosphoric acid costs $14 per ton, this would mean a cost of 5 cents a pound for the available phosphoric acid, provided the value of the insoluble phosphoric acid is ignored. In the same way we may reach the cost of potash in its various forms. Pound prices for these ingredients so determined have been used to a large extent in making valuations of complete fertilizers, a matter which will be more fully discussed later.

The agricultural value to a particular farmer of any fertilizing ingredient in a given form depends on its efficiency in crop production and its adaptability to the farmer's needs. A schedule of agricultural values of the various fertilizing ingredients as derived from different sources cannot be given. It is not possible to formulate such values on a theoretical basis, and the experimental evidence at hand does not justify a statement of definite relations. Indeed, so great are the differences in the effect of a particular fertilizer, due to locality, crop and season, it is quite evident that no universal comparative valuations on the basis of agricultural efficiency are possible. It will remain for each consumer to make his own estimates of values as applying to his special conditions. At the same time, there are some facts of universal interest and application.

In the case of nitrogen we must regard it as most immediately efficient when in the form of the nitrate. The fact that nitrogen enters the plant, it is believed, mostly in the form of nitrates, justifies this conclusion, as also does experimental evidence. Of practically equal value is nitrogen as an ammonia salt. In the case of organic nitrogen, we can say that, in general, its value depends on the readiness of decomposition of the animal or vegetable substances containing it. Such substances as ground meat, pure dried blood, cottonseed meal and all others that promptly break down in the soil through fermentations, have a high agricultural value, perhaps practically not greatly inferior to that of nitrates and ammonia salts, while the nitrogen in tankage and bone is less efficient. Because of the great slowness of decomposition of untreated hoof, horn, hair, leather, shoddy and similar materials, the nitrogen in these is regarded as having a very inferior value.

The same general principles apply to the various forms of phosphoric acid. Phosphoric acid, soluble in water, is properly regarded as being in the most valuable condition, for while it does not remain soluble when in contact with the soil, when applied in a soluble form it is readily diffusible, and as is shown abundantly by experimental data, is promptly available to growing crops. The results of investigation go to show that the reverted phosphoric acid, that is, phosphoric acid which has been in a soluble form and through chemical reactions is changed to the di-calcic or other forms, has essentially the same value for feeding plants that the soluble forms of phosphoric acid have. While this statement is doubtless true of really reverted phosphoric acid, it is by no means proved that all that which is rendered soluble by ammonium citrate (a reagent used for dissolving so-called reverted phosphoric acid) has a value equal to that of the soluble forms; and for this reason the reverted, or available phosphoric acid, as determined in fertilizers by the usual methods of analysis, has an indefinite value.

The crop-producing value of finely ground mineral phosphates varies with the material and with the conditions of use. The crystalline phosphates, such as apatite, give up their phosphoric acid to soil solutions with such slowness as to have little value for feeding plants. Finely ground South Carolina rock, or similar material, sometimes known as floats, is often used with good results. The phosphatic slag known as Thomas slag, when finely ground, is being used very successfully as a source of phosphoric aid, especially in certain parts of Europe. Redonda phosphate, which is chiefly an aluminum phosphate, after being heated to a certain degree gives off water of hydration, and this dehydrated material has been found to be available to plants under certain conditions. It should be borne in mind that these slowly acting materials are especially adapted to fruit trees and other growing plants when the effect of the fertilizers is extended over long periods of time. It is rational to conclude, moreover, that these insoluble phosphates would have a maximum effect on soils rich in humus, that is, soils naturally acid, and that the minimum effect would be seen on limestone soils.

Expenditures for commercial fertilizers.

The expenditures for commercial plant-food in the United States are large. The census of 1900 reports that the sum paid by consumers of commercial fertilizers in 1899 was $54,783,757. For the censuses of 1880 and 1890, the expenditures reported were $28,586,397 and $38,469,598, respectively, an increase of expenditure of 34.6 per cent from 1880 to 1890, and 42.4 per cent from 1890 to 1900. This increase in the use of fertilizers was not uniform throughout the United States, being much more rapid in the north central and in the western states, the increase for the last decade in the former section being 137 per cent and in the latter section 342.7 per cent, thus illustrating the well-known fact that, the older the agriculture in any given section, the more extensive the use of commercial fertilizers is likely to be.

The value of the fertilizers manufactured in the United States by 478 establishments was found to be $46,011,382, the output being 3,091,717 tons. Of this quantity, 57.2 per cent consisted of complete fertilizers, that is fertilizers carrying nitrogen, phosphoric acid and potash, 5.4 per cent ammoniated superphosphates, that is, fertilizers without potash, 18.7 per cent superphosphates (acid phosphates), and 18.8 per cent of other fertilizers, which include such materials as fish scrap, dried blood and all other animal and special products which are sold in the uncompounded state. This large expenditure for fertilizing material was chiefly in the North Atlantic and South Atlantic divisions, over 70 per cent of the entire consumption being found in the eighteen states comprised in these sections. The heaviest expenditure per farm and per acre is seen to be in the market-gardening states, New Jersey taking lead with an average expenditure of $62 per farm, or 76 cents per acre. In some states the expenditure ranged from 5 to 6 per cent of the total value of the farm products.

Fertilizer inspection and control.

It became evident early in the history of the fertilizer trade that some form of control that should guarantee to purchasers goods of the quality that was claimed for them, would be necessary. There are no exterior characteristics, such as texture, color and odor, by which the commercial value of a fertilizer may be even approximately determined, neither can this be done by field tests, and consequently, without inspection, it is easy to palm off fraudulent goods. Active inquiry into the character of the fertilizers in the market began in the early seventies, since which time between thirty and forty states have enacted laws providing for the inspection of fertilizers and the control of their sale. The department or official to whom the administration of the fertilizer law is entrusted, is sometimes a state department of agriculture or its executive officer, sometimes the director of an experiment station, and sometimes an especially appointed official, such as a state chemist. The laws of the several states set forth the following requirements, some of which are uniformly insisted on:

(1) A certificate must appear attached to each package of fertilizer, that states the percentage of nitrogen, available phosphoric acid and potash soluble in water, which that particular brand of goods is guaranteed to contain. Sometimes it is required that nitrogen shall be stated in terms of that which is available and sometimes the proportions of the various forms of phosphoric acid must be stated. In some states it is required that if ingredients of an inferior character are used, the certificate attached to the package shall so state.

(2) In many states, at least, a certificate corresponding to that which is attached to the fertilizer packages must be filed with the executive officer of the fertilizer law.

(3) In most states having a fertilizer law, a money tax or license fee is placed on the fertilizer trade for the support of the work of inspection. The manner in which this tax is placed varies greatly with different states. The various methods are: a general license requiring the payment of a lump sum; a license fee, the amount of which is graded by the quantity of fertilizer sold; a brand tax; a fee for the required analysis of samples submitted to the proper state official, and a fee for labels which the manufacturers must purchase of the state.

(4) A penalty is uniformly imposed for a violation of the requirements of the law, such as a failure to attach a certificate to the packages, to file the required statement with the proper state official, or the selling of goods containing materially less proportions of the valuable ingredients than was guaranteed.

(5) It is required of the department or official charged with the administration of the law that samples of fertilizers as found in the market shall be taken and submitted to chemical analysis in order to determine whether the goods have a composition which meets the guarantees. In case the department or official becomes cognizant of a violation of the law, there is required either a direct prosecuting of the offenders or the reporting of the violation to some designated state official.

Though not required to do so by law, some of the older experiment stations have presented information in the bulletins giving the results of inspection as to the selling price and commercial valuation of the various brands inspected. This commercial valuation was based on the pound cost of nitrogen, phosphoric acid and potash as purchased in chemicals and raw materials in the large markets. The publication of such valuations was not universally adopted and is now held in more or less disfavor by inspecting officials. The advantage of this practice consisted in placing in the hands of consumers an easy means of determining whether any given brand of fertilizer was being sold at a price out of proportion to its commercial value, a method of comparison exceedingly useful when used with discrimination. The arguments against such valuations, which have led to their abandonment in some instances, are that the valuations of different brands are likely to be compared by the indiscriminating on an unfair basis, and that the commercial value is confounded with agricultural value.

To illustrate, a fertilizer carrying 6 per cent of phosphoric acid and 5 per cent of nitrogen would have a higher commercial valuation than one carrying 12 per cent of phosphoric acid and 2 per cent of nitrogen, but it would be unfair to claim superiority for the former brand simply because it would cost more in the market. The difference in the cost of the two lies in the fact of the larger proportion of nitrogen in the former, and it would not follow that it would be wise to purchase the former simply because of its higher valuation. This is equivalent to saying that high valuations are not necessarily an indication of high agricultural value for use under given conditions. The agricultural value of a particular fertilizer to a given consumer is determined by the profits from its use, that is, its efficiency in promoting larger crop production on his land. It is entirely possible that a ton of acid phosphate costing $14 would return larger profits under some conditions than a ton of dried blood costing $30. The agricultural value, then, is determined by composition and not by cost, and the disadvantage, to some extent, of the system of valuations followed by certain experiment stations was that consumers confounded cost with value in their own practice.

The legal control which the various states have assumed over the fertilizer trade has become most efficient. Probably no industry in the country is more amenable to legal control than is the manufacture and sale of fertilizers. The benefits of such control are evident and are realized by both manufacturer and consumer. The manufacturer is defended against competition with goods that are sold on a fraudulent basis, and the consumer is guaranteed the purchase of materials fairly comparable with the composition that is claimed. Many instances could be cited of the final exclusion from the market of fraudulent mixtures which otherwise would have maintained more or less hold on the market for a long time, as for instance Poplein's Silicated Fertilizer, which was extensively exploited in the seventies, and later other mixtures of an equally inferior character. A very large proportion of the brands of fertilizers now in the market may be regarded as reliable and of fairly uniform composition. Moreover, the literature issued by the inspecting departments or officials is widely distributed among purchasers, who now have the opportunity of obtaining definite knowledge of what they are buying, which would not be possible without the existing inspection.

The purchase of commercial fertilizers.

The opportunities that are presented for the purchase of commercial fertilizers in the United States involve peculiar, and, to some extent, unsatisfactory conditions. In the first place, the number of brands offered in the market is very large, the brand names numbering among the hundreds. If these brands represented characteristic differences in composition, the situation would be more rational. They exist, however, because of what is regarded as necessary commercial expediency, the large number of manufacturers believing it to be essential to their business that they use trade names of a proprietary character. The trade names must be regarded in many cases as altogether unfortunate. They often imply facts which do not exist and more often are of such a character as to relegate the fertilizer trade to the atmosphere of the patent medicine business. It is probable that twenty-five different mixtures at the outside would meet all the demands of the trade or of the farmers, and thus simplify very greatly what is to the purchaser a confusing situation.

Another condition that is unfortunate for the consumer, but for which he is largely responsible, is the presence in the market of a large number of low-grade mixtures, that is, low grade in the sense of carrying small percentages of valuable ingredients. An analytical review of the fertilizer trade in the state of New York for the year 1902 revealed the fact that 171 brands, or 25 per cent of all those in the market, were of a low-grade character, carrying on the average only 1.2 per cent of nitrogen, 8.2 per cent of phosphoric acid and 2.6 per cent of potash. As suggested, these brands exist because of a demand on the part of the farmers for low-priced goods. To purchase such goods is mistaken economy.

A comparative study of the composition and selling prices of low grade and high grade goods revealed the fact that in the former the valuable ingredients had a pound cost over one-third higher than was the case with the latter. It is very evident that manufacturers cannot afford to mix a given quantity of valuable ingredients in an unnecessarily large tonnage and distribute this diluted, or low grade material, to consumers without increasing the cost over that which would attend more highly concentrated materials. To illustrate, the valuable ingredients of a ton of fertilizer carrying 1.2 per cent of nitrogen, 8.2 per cent of phosphoric acid and 2.6 per cent of potash, could be procured in 1,200 pounds of 14 per cent acid phosphate, 163 pounds of nitrate of soda and 140 pounds of muriate of potash, in all 1,500 pounds, showing that in sending out a low grade mixture freight is paid on 500 pounds of unnecessary material. If the nitrogen is furnished in 10 per cent dried blood, the increase in weight would be less than 100 pounds.

It is said by many farmers that they cannot afford to pay the price of high grade materials. In making this assertion it is forgotten that a smaller quantity of a high grade mixture will do the work of a larger quantity of the low grade. The expenditure should be based on the pounds of valuable ingredients obtained and not on the total weight of the mixture.

The expensiveness of commercial fertilizers to consumers is also increased by the fact that the trade is conducted largely on the credit system, and by means of agents who are abundantly distributed through the rural districts and who handle only small quantities of goods. A much better system of distributing plant-food to consumers would be the sale by the established merchants of cities and villages of standard materials to be sold under proper descriptive names, the prices to be based strictly on composition. This would place the purchase of commercial plant-food on a rational and much more economical basis.

For many years, the leaders in agriculture have advocated the home-mixing of fertilizers, that is, the purchase of chemicals and raw materials and the mixing of the same on the farm in such proportions as is believed by the farmer to best suit his needs. This system has not made rapid headway despite its many evident advantages, for reasons which are not altogether obvious. Home-mixing is entirely possible and practicable, because the chemicals and raw materials in the market are in efficient forms adapted to immediate use without any further manipulation. It is not true that the ingredients of a mixture of acid phosphate, potash salts and ammoniates have any greater efficiency when compounded by a fertilizer manufacturer than when compounded by a farmer. It has been shown, moreover, that the mechanical condition of the manufacturers' output is no better than that of the farmer's mixture.

There are certain advantages which pertain to home-mixing, especially when practiced by those who are using large quantities of commercial fertilizers. In the first place, market conditions have so far been such, even in the retail trade, that chemicals and raw materials have offered valuable fertilizing ingredients at less cost than the manufacturers' mixtures. This difference has been large. In the second place, by the purchase of chemicals and raw materials it is easily possible for the farmer to adapt the materials used to his needs, however unlike these needs may be for his different farm operations. In the third place, it is possible to so purchase chemicals and raw materials as to have entire assurance that they are of high quality. This is not true to the same extent of the manufacturers' mixed goods.

It is urged against home-mixing that farmers do not know what they should purchase, but it is clear at least that intelligent farmers are better qualified to judge of their needs than is the distant manufacturer who is only rarely well informed in farm practice, or the special needs of particular localities.

It is also asserted that much trouble attends the practice of home-mixing of chemicals and raw materials. It is certainly doubtful whether consumers who use only a few hundred pounds of commercial fertilizer can afford to take the trouble of purchasing the ingredients and mixing them themselves. The large farmer, using generous quantities of commercial fertilizer, can certainly afford to do so; and in any case farmers may wisely combine and purchase the necessary ingredients by the car-load. The mixing itself is a very simple matter, involving only a smooth barn floor and a shovel. It should be suggested in this connection that in mixing what is known as a complete fertilizer, that is, one containing compounds of nitrogen, phosphoric acid and potash, part of the nitrogen at least should be introduced in the form of organic material, or else the mixture should be put together only a brief time before it is used. If these precautions are not observed, the mixture is likely to "cake" and be undesirable for sowing either by hand or through a drill.

Literature.

It is impossible to give in this place a comprehensive bibliography of the literature on fertilizers. This literature is extremely varied and voluminous. Most of the experiment stations have issued bulletins of fertilizer analyses and tests. The experiment stations in Rhode Island, Massachusetts, New York, New Jersey, Vermont, Ohio and Kentucky have given special attention to the subject. The United States Department of Agriculture has also issued a number of valuable bulletins on fertilizers. Only a few references can be given: Fertilizers, by E. B. Voorhees; The Fertility of the Land, by I. P. Roberts; chapters in Storer's Agriculture; Fertilizers and Feeding Stuffs, by Bernard Dyer, London, 1903; Bone Products and Manures, by Thomas Lambert, London, 1901; Artificial Manures, by Alfred Sibson, London, 1901; Fertilizer Laws of the Various States, by T. Breyer and H. Schweitzer, Chemists' Pocketbook, 1893; Potash in Agriculture, results obtained in the United States, B. von Herff, Baltimore, 1893; Florida, South Carolina, and Canadian Phosphates, by C. C. H. Millar, London, 1892; The Phosphates of America, by Francis Wyatt, New York, 1892; Chemicals and Clover, or Farming with Concentrated Dung, by H. W. Collingwood, New York, 1892; Tabulated Analyses of Commercial Fertilizers from Samples Selected in Accordance with act of June 28, 1879, Pennsylvania State Board of Agriculture, Harrisburg, 1891; Nature and Origin of Deposits of Phosphate of Lime, by R. A. F. Penrose, United States Geological Survey Bulletin, No. 46, 1888; Agricultural, Botanical and Chemical Results of Experiments on the Mixed Herbage of Permanent Meadow, Conducted for more than Twenty Years in Succession on the Same Land, by Sir J. B. Lawes and J. H. Gilbert, in Rothamsted memoirs (see also Philosophical transactions, Pt. I, 1880, Pt. IV, 1882, Vol. 2, 1886); Chemical Conversion Tables for Use in the Analysis of Commercial Fertilizers, by F. B. Dancy and H. B. Battle, Raleigh, 1885; Talks on Manures, by Joseph Harris, New York, 1878; On the Connection between Manures Made on the Farm and Artificial Manures, a lecture by Sir J. B. Lawes, Haddington, England, 1877; A Practical Treatise on Pure Fertilizers and the Chemical Conversion of Rock Guanos, Marlstones, Coprolites, and the Crude Phosphates of Lime and Alumina into Valuable Products, by Campbell Marfit, London, 1873; Commercial Fertilizers, by Peter Collier, Montpelier, Vt., 1872.

Besides the publications referred to above, numerous valuable addresses before agricultural organizations and conventions have appeared from time to time in the reports of societies and of state departments and boards of agriculture. Publications of this character issued by the states of Connecticut, Maine, Massachusetts, New York and Pennsylvania, should be especially mentioned in this connection. German and French literature also present many results of investigations of plant-nutrition problems that are of a fundamental character and are important in American farm practice.

CULTURE EXPERIMENTS FOR DETERMINING FERTILIZER NEEDS

By *Cyril G. Hopkins*

In conducting experiments in the field or by pot cultures to determine what plant-food element limits the crop yield, special care must be taken to avoid indirect or secondary influences. Thus, in the selection of plant-food carriers, soluble salts and low-percentage materials should be avoided, if possible, because of the secondary effects which they may produce. This article deals with soil experiments, that is with experiments to determine what element or elements may be deficient in the soil. Experiments to determine the comparative value or availability of different carriers of the same element are properly called fertilizer experiments. [See also pages 134 and 365.]

Kinds of plant-food materials.

Nitrogen.—As a nitrogen fertilizer, dried blood carrying 14 to 15 per cent of nitrogen is the most satisfactory form for experiments. It is a readily available and concentrated nitrogen carrier. It is not soluble in water and will produce no secondary effects unless its decomposition products slightly influence the liberation of other plant-food and affect the physical properties of the soil by the small addition of humus. These secondary effects are appreciable with less concentrated forms of organic nitrogen, as cottonseed meal.

Sodium nitrate is objectionable because it is a soluble salt and also because the element sodium, which is present in larger amount than the nitrogen, is a strongly alkaline base that, after the nitrogen has been taken up by the plant, largely remains in the soil and may correct soil acidity or displace and liberate equivalent amounts of potassium, calcium, magnesium, and the like, from the mineral constituents of the soil. These secondary effects of sodium nitrate are especially noticeable on legume crops, as clover, which is markedly benefited by the correction of soil acidity and by the liberation of mineral plant-food, while, if infected with the proper bacteria, it is practically independent of the supply of nitrogen in the soil. Since a good growth of clover is usually of great benefit to succeeding crops in the rotation, this indirect or secondary effect of sodium nitrate, which may be the means of saving the life of the plant at a critical period in unfavorable seasons, may exert a more beneficial influence on the entire crop rotation than the effect due to the nitrogen applied.

Ammonium sulfate is objectionable as a nitrogen fertilizer for experimental work because ammonium also acts as a strong base, becoming quickly, though temporarily, fixed in the soil and liberating mineral bases. Furthermore, as the ammonia nitrogen nitrifies and is taken up by the crop, the sulfuric acid radicle tends to increase the acidity of the soil until it may become injurious to certain crops, notably clover and barley.

Phosphorus.—As a phosphorus fertilizer, steamed bone-meal, carrying 12 to 14 per cent of the element phosphorus, and very finely ground natural rock phosphate, which is as rich in phosphorus as steamed bone, are satisfactory carriers. The bone-meal when well-steamed and finely ground is readily available and contains less than 1 per cent of nitrogen, which is in organic form and probably no more effective than the small amount of soluble nitrogen usually contained in acid phosphate. Rock phosphate is not readily available and must be applied in larger quantities if substituted for steamed bone-meal.

Acid phosphate is objectionable because it contains a soluble, corrosive acid salt, $H_4\,Ca(PO_4)_2$, and a much larger quantity of soluble calcium sulfate formed in the process of manufacture. Calcium sulfate (land-plaster) is a well-known and very effective soil stimulant, having power to liberate mineral plant-food from the soil, and thus for a time to increase the growth of plants, especially of clover and other crops requiring much potassium. High-grade acid phosphate contains but 7 per cent of the element phosphorus, being only one-half as concentrated as steamed bone or natural rock phosphate.

Slag phosphate is objectionable because it is a strongly alkaline material, carrying some caustic lime which corrects soil acidity and which also acts as an effective soil stimulant, both in liberating mineral plant-food and in promoting nitrification. Slag phosphate is also much less concentrated than steamed bone.

Raw bone-meal is not satisfactory because it carries too much nitrogen. It is also poorer in phosphorus and less readily available than steamed bone-meal.

Potassium.—There is no potassium fertilizer which is satisfactory for use in culture experiments for determining which element of plant-food limits the crop yield. Potassium sulfate carrying 40 per cent or more of potassium is the least objectionable, but even this is a water-soluble salt capable of disturbing to a greater or less extent the chemical equilibrium of the soil. It is well known that the solubility of tricalcium phosphate, is appreciably increased by small amounts of soluble potassium salts, doubtless because of the formation of some potassium phosphate. Sodium salts also increase the solubility of tricalcium phosphate in laboratory experiments and, while sodium chlorid when applied to the soil tends to liberate potassium, calcium, magnesium and others, it is evident that the increased crop yields resulting from applications of common salt are in some cases produced by the phosphorus thus made available rather than by the potassium liberated.

As a potassium fertilizer, the chlorid possesses the same objectionable qualities as the sulfate, and in addition it tends to form calcium chlorid which may become injurious to crops if it remains in the soil ; or if it passes off in drainage water, as it is likely to do because of its great solubility, it reduces the calcium or lime content of the soil, thus hastening soil acidity.

Kainit is very objectionable as a carrier of potassium not only because it consists of soluble salts of potassium, magnesium and sodium, but also because it contains only 10 per cent of potassium, so that four times as much kainit as potassium sulfate would be required for equal applications of potassium. In some cases the indirect effect of kainit (and possibly even of potassium sulfate or chlorid) is greater than the effect due to the potassium as plant-food.

Amounts of plant-food materials.

The amount of dried blood, steamed bone, and potassium sulfate to use in experimental work should be governed by the requirements of the crop for approximately maximum crop yields. Thus a crop of average corn, yielding 100 bushels of grain and three tons of stover per acre, will contain about 148 pounds of nitrogen, 23 pounds of phosphorus, and 71 pounds of potassium; while 1,000 pounds of dried blood, 200 pounds of steamed bone-meal, and 200 pounds of potassium sulfate, should supply 150 pounds of nitrogen, 25 pounds of phosphorus, and 80 pounds of potassium. As an initial application, that is for the first year, it is well to apply double the standard amount of steamed bone because it is less readily available than dried blood and potassium sulfate. For wheat or oats the nitrogen may be reduced to one-half and the phosphorus and potassium to two-thirds of these amounts. For a crop of a different class of plants, as sugar-beets, quite different proportions and amounts may be needed; while, for a rotation of crops including a liberal use of legumes and some farm manure, the application of commercial nitrogen should be entirely omitted and the amounts of mineral elements may be reduced; and, with liberal quantities of farm manure containing both solid and liquid excrement, the phosphorus may be reduced and the commercial potassium may be greatly reduced or entirely omitted.

Specific examples of culture experiments.

The following examples will illustrate systems of pot cultures and plot experiments and at the same time show the actual results secured on different soil types.

(a) *Soil deficient in nitrogen.*—Much of the rolling or sloping unglaciated hill land in the southernmost seven counties of Illinois has been under cultivation 75 to 80 years. This was originally a fairly productive soil, 25 to 30 bushels per acre of wheat having been common yields. Through loss of nitrogen by continuous cultivation in corn and other grain crops and by surface washing, the productive capacity has been so reduced that five bushels of wheat per acre is now the average yield on the worn soil.

A series of pot culture experiments conducted in 1902 gave the results shown in Table I. Common glazed earthenware, 4-gallon jars, 10½ inches in diameter, are used. A half-inch hole is punched through the bottom and covered with copper gauze and a bunch of glass wool for drainage. The pot is half filled with soil collected 5 to 10 inches below the surface, and then filled with soil from the surface 5 inches with which the plant-food is thoroughly mixed. Pot cultures yield two to three times as much comparatively as is obtained under field conditions, and plant-food is added accordingly, 15 grams of dried blood, 3 grams of steamed bone (6 grams the first year), and 3 grams of potassium sulfate being the usual annual applications.

TABLE I.—WHEAT YIELDS FROM SOIL DEFICIENT IN NITROGEN.

No.	Red silt loam hill land of the unglaciated area, Illinois Plant food applied	Wheat (grain) in 1902 (Grams per pot)
1	None	3
2	None	4
3	Nitrogen	26
4	Phosphorus	3
5	Potassium	3
6	Nitrogen, phosphorus	34
7	Nitrogen, potassium	33
8	Phosphorus, potassium	2
9	Nitrogen, phosphorus, potassium	34

The chemical analysis of this soil showed that it was very deficient in nitrogen, while moderately supplied with phosphorus and rich in potassium. The pot cultures gave results in accord with the chemical composition, except that potassium when added to nitrogen increased the yield from 26 grams (No. 3) to 33 grams (No. 7), but this increase was probably due not to the effect of potassium as added plant-food but rather to the additional supply of phosphorus made available by the soluble potassium salt.

The marked effect of nitrogen suggests, not that commercial nitrogen should be purchased and used on this soil, which would be too expensive to be profitable in general farming, but that liberal use should be made of legume crops as catch-crops or in rotation. As soon as the wheat was harvested cowpeas were planted in No. 2, and later in the season they were turned under as a catch-crop. In 1903 wheat was again grown on all the pots, and a second legume catch-crop was grown after the wheat on No. 2. This was repeated in 1904, and again in 1905, with the results shown in Table II:

TABLE II.—WHEAT YIELDS FROM SOIL DEFICIENT IN NITROGEN.

No.	Red silt loam hill land, unglaciated area, Illinois Soil treatment applied	1902 Wheat (grams)	1903 Wheat (grams)	1904 Wheat (grams)	1905 Wheat (grams)
1	None	3	5	4	4
2	Legume catch-crop	4	10	17	26
3	Nitrogen	26	17	14	15

The notable gain of the legume treatment over the commercial nitrogen treatment after the second catch-crop had been turned under is doubtless due not to a more abundant supply of nitrogen furnished but to the supply of phosphorus liberated in part from the legume crop residues and in part from the soil itself in contact with the decaying organic matter. (See Figs. 641 and 642.) These pot-culture tests have now been confirmed by field experiments.

Fig. 641. Pot cultures of wheat (1902). Soil deficient in nitrogen; commercial nitrogen applied to pot 3 (on right). See Table II.

(b) *Soil deficient in phosphorus.*—The principal type of soil in more than 20 counties in southern Illinois (lower Illinois glaciation) is markedly deficient in phosphorus, moderately supplied with nitrogen, and fairly rich in potassium, as judged by chemical analysis in comparison with normal fertile soils.

Table III gives the results of field experiments with wheat in 1904, on tenth-acre plots on the University of Illinois soil experiment field near DuBois, Washington county, Illinois:

TABLE III.—WHEAT YIELDS FROM SOIL DEFICIENT IN PHOSPHORUS.

Gray silt loam prairie, lower Illinois glaciation Plant-food applied	Wheat bushels per acre
None	7
Nitrogen	11
Phosphorus	25
Potassium	16
Nitrogen, phosphorus	33
Nitrogen, potassium	20
Phosphorus, potassium	28
Nitrogen, phosphorus, potassium	33

A gain of 18 bushels per acre was produced by the phosphorus even when applied alone; and when phosphorus was applied after nitrogen the yield was increased from 11 bushels to 33 bushels per acre, making a gain of 22 bushels per acre under field conditions. Nitrogen increased the yield somewhat (4 bushels) and the increase became more marked (8 bushels) after phosphorus had been applied, as would be expected; but the gain of 9 bushels per acre (7 to 16) made by applying potassium alone, and the gain of 9 bushels (11 to 20) made by adding potassium to nitrogen, may rightly be considered as evidence that the soluble potassium salt has produced this increase not because of the potassium added as plant-food but rather by the phosphorus liberated from the soil. This evidence is strengthened by the fact that nitrogen and phosphorus without potassium produced as large a yield as when potassium also was added. It may be stated that an entirely independent duplicate series of plots on this experiment field produced very similar results.

Table IV gives three years' results in wheat-growing on this same type of soil in a different system of plot experiments, conducted on fifth-acre plots on the University of Illinois soil experiment field near Odin, Marion county, Illinois. A four-year rotation is being practiced on four different series of plots, each crop thus being represented every year. No nitrogen has been added except by growing legume crops and catch-crops in a rotation of corn, oats, wheat and cowpeas. The legume treatment for 1903 consisted of a catch-crop of cowpeas grown after oats in 1902. The legume treatment for the 1904 wheat consisted of catch-crops of cowpeas in the corn in 1902 and after the oats in 1903. For the 1905 wheat crop the previous legume treatment has been a full crop of cowpeas turned under in 1902, and catch-crops of cowpeas in the corn in 1903 and after the oats in 1904. No legumes are grown on the check plot except in the regular rotation crop, and that is harvested and removed.

TABLE IV.—WHEAT YIELDS FROM SOIL DEFICIENT IN PHOSPHORUS.

Gray silt loam prairie Lower Illinois glaciation	Average of two series each year		
Soil treatment applied	1903 Wheat	1904 Wheat	1905 Wheat
	Bu.	Bu.	Bu.
None	1	7	13
Legume	1	7	18
Legume, lime	1	10	24
Legume, lime, phosphorus	10	22	36
Legume, lime, phosphorus, potassium	15	25	32

The season of 1903 was very poor for wheat, 1904 was fairly normal, while 1905 was exceptionally good, as indicated by the yield on the untreated plots. The soil is acid, and lime produces an appreciable increase in the growth of legumes. The legume crop residues not only supply nitrogen but as they decay they evidently liberate some phosphorus and ultimately abundant potassium for the wheat crop. It is noteworthy that while potassium produced a

Fig. 642. Pot cultures of wheat (1905). Same soil as described in Fig. 641, deficient in nitrogen. No. 1 (on left) received no plant-food; No. 2, received legume catch-crops; No. 3 (on right) received commercial nitrogen. See Table II.

marked increase in 1903, and a smaller increase in 1904, it decreased the yield of wheat in 1905, in each of duplicate tests. It is also noteworthy that the addition of potassium increased a yield of 10 bushels by 50 per cent in 1903, whereas in 1905 the maximum yield of 36 bushels per acre was produced without potassium. Phosphorus produced a gain of 9 bushels in 1903, 12 bushels in 1904, and 12 bushels in 1905. (Fig. 643.)

Fig. 643. Field experiments with wheat. Soil deficient in phosphorus. Plot 3 (on left) received legume catch-crops and lime; plot 4 (on right) received legume catch-crops, lime and phosphorus. See Table IV.

Table V gives results secured in 1903 on the University of Illinois soil experiment field on the estate of Hiram Sibley (founder of the Sibley College of Cornell University), located on typical Illinois corn-belt soil in Ford county, Illinois. The analysis of this soil shows that the total supply of phosphorus is below that in the more highly productive soils, that the nitrogen is somewhat better supplied, while the supply of potassium is very large.

TABLE V.—CORN YIELDS FROM SOIL DEFICIENT IN PHOSPHORUS.

Brown silt loam prairie, early Wisconsin glaciation / Plant-food applied	1903 Corn, bushels per acre
None	54
Nitrogen	54
Phosphorus	62
Potassium	50
Nitrogen, phosphorus	69
Nitrogen, potassium	51
Phosphorus, potassium	61
Nitrogen, phosphorus, potassium	64

It will be observed that phosphorus produced an increase in each of the four tests amounting to eight bushels when applied alone and fifteen bushels when applied after nitrogen. Nitrogen produced no increase when applied alone, but made gains of three to seven bushels after phosphorus had been applied. It is noteworthy that in each of the four tests a decrease in yield has followed the application of potassium.

(c) *Soil deficient in potassium.*—In northern and north-central Illinois are extensive tracts of peaty swamp soil that is not only exceedingly rich in nitrogen and phosphorus and markedly deficient in the element potassium, as compared with normal fertile soils, but the potassium present is evidently quite unavailable under the present conditions. In places, the subsoil is of a clayey nature and when within reach of the plow it may be brought to the surface with marked benefit; but frequently the peaty material is deep or underlain with sand, and sometimes the soil only a few inches beneath the surface contains a high percentage of "alkali," including much magnesium carbonate, in which the roots of some plants, especially of corn, seem incapable of living. Table VI gives the very marked results secured in 1903 on the University of Illinois soil experiment field near Momence, Kankakee county, Illinois:

TABLE VI.—CORN YIELDS FROM SOIL DEFICIENT IN POTASSIUM.

Peaty swamp land / Plant-food applied	Corn, bushels per acre	Stover, pounds per acre
None	7	820
Nitrogen	4	750
Phosphorus	5	1,040
Potassium	73	3,770
Nitrogen, phosphorus	4	730
Nitrogen, potassium	71	3,160
Phosphorus, potassium	73	3,380
Nitrogen, phosphorus, potassium	69	3,010

Very similar though less striking results have been obtained from this and other experiment fields on soils of this class during the past four years. (See Fig. 644.)

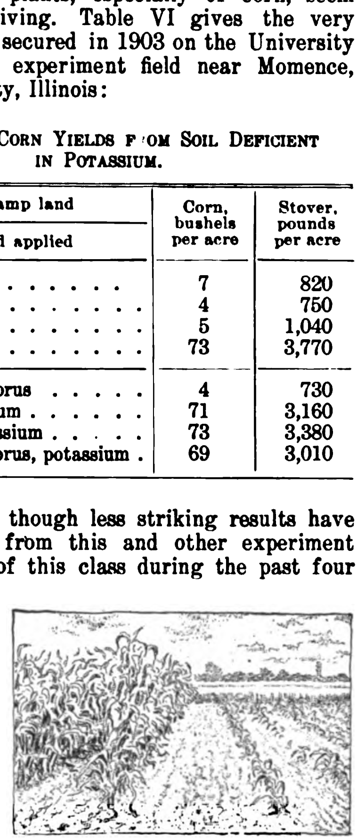


Fig. 644. Field experiments with corn. Soil deficient in potassium. Plot on left received commercial potassium; plot on right received both nitrogen and phosphorus.

Conclusion.

In considering the general subject of culture experiments for determining fertilizer needs, emphasis must be laid on the fact that such experiments should never be accepted as the sole guide in determining future agricultural practice. If the culture experiments and the ultimate chemical analysis of the soil agree in the deficiency of any plant-food element, then the information is conclusive and final; but if these two sources of information disagree, then the culture experiments should be considered as tentative and as likely to give way with increasing knowledge and improved methods to the information based on chemical analysis, which is absolute.

Literature.

The following publications discuss in some measure culture experiments to determine fertilizer needs: Boussingault (1848), Rural Economy, (Law's Trans.); Liebig (1863), The Natural Laws of Husbandry, (Blyth's Trans.); United States Department of Agriculture, Office of Experiment Stations, Bulletin No. 22 (1895), Agricultural Investigations of Rothamsted, England (there are also many earlier reports of the Rothamsted experiments); Wagner (1891), Die Rationelle Dungung der landwirthschaftlichen Kulturpflanzen (this is only one out of many of Wagner's publications on culture experiments); New York (Cornell) Bulletin No. 129 (1897), How to Conduct Field Experiments with Fertilizers; Illinois Bulletin No. 76 (1902), Alfalfa on Illinois Soil; Illinois Bulletin No. 93 (1904), Soil Treatment for Peaty Swamp Lands; Illinois Bulletin No. 99 (1905), Soil Treatment for the Lower Illinois Glaciation; Illinois Circular No. 96 (1905), Soil Improvement for the Illinois Corn Belt.

PARAFFINED-POT METHOD FOR DETERMINING THE MANURIAL REQUIREMENTS OF SOILS.

By *Frank D. Gardner*

This method of determining the manurial requirements of soils consists of growing plants in small, paraffined wire pots containing soil to which have been added fertilizers of different kinds and in different quantities. The pots are planned to make possible a comparison of the several fertilizer ingredients within a period of about three weeks by means of the appearance and growth of the plants; or the effect of the treatments may be actually measured by cutting and weighing the plants, or by measuring the transpiration of the plants during the period of growth.

Description of the paraffined pot.

A special form of small pot is used. It consists essentially of soil in a wire frame surrounded by a coat of paraffin that penetrates partly into the soil, thus cementing the outer layer of soil to the vessel of paraffin. The essential feature of this is that there is no space between the soil and the pot in which the roots can develop, as is usual in other forms. In this special form of paraffined soil pot the roots are compelled to stay in the soil and tell the story of the soil, whether it be good or bad, and the relative influence of the fertilizers on it. Wheat plants are usually grown in these pots 15 to 20 days, the various fertilizer salts, organic manure or other treatment having been made on the soil previous to putting it into the pot.

This method, as outlined, is designed for both the farmer and the practical soil investigator. It affords a ready means of determining the fertilizer or manurial requirements of a soil by getting indications in this small way, with a saving of time and labor, and the avoidance of a possible failure of returns from the use of a fertilizer to which the soil does not respond.

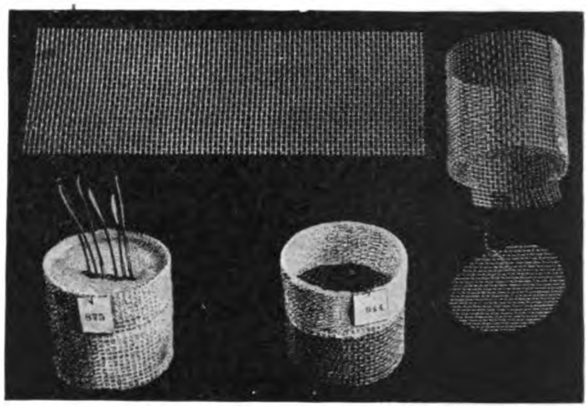


Fig. 645. Method of constructing the wire pot or basket.

In addition to the wire pots, the necessary apparatus includes some paraffin, an inexpensive substance that can be procured from any drug-store, and, for the weighing tests, a pair of scales that will weigh accurately to one-fourth ounce. The pots are made from galvanized-wire net having one-eighth-inch mesh, and are of simple construction (Fig. 645). The net is cut into strips 3½ inches wide by 10 inches long. The ends are brought together and fastened by short rivets. At intervals along one end of the cylinder thus formed, vertical incisions one-half inch long are made, and the ends are turned in to hold the bottom, which consists of a disc of the same material. The top of the pot is then dipped into hot paraffin to the depth of about one inch, removed and dipped again, until a rim of paraffin is formed. Numbers are then attached to the pots for the purpose of identifying them, and in order that a record of each may be kept in case it is so desired. For convenience in handling, it is advisable to place the pots in shallow boxes or trays, twenty, more or less, in each. This completes the construction of the wire pot up to the time of filling it with soil.

Preparing the soil.

The soil to be tested should be representative of the field from which it is taken. A representative sample is usually secured by taking a number of small samples from different parts of the field and thoroughly mixing them. From this mixture the portions that are to be treated with fertilizers are taken, the number of portions required being one greater than the number of kinds of treatment it is desired to test.

The quantity of fertilizer added should correspond closely to the quantity used in field practice. To add these fertilizers in the proper proportions to the samples to be tested, the following procedure is suggested : To 7¾ pounds of dry, well-pulverized soil add 1 ounce of the desired fertilizer. Mix very thoroughly and pass through a sieve at least twice. This mixture is still much too strong for use, and it is further diluted by adding one ounce of it to 5 pounds more of soil, mixing thoroughly as before. This new mixture contains fertilizer at the rate of 200 pounds per acre. When larger applications are desired, proportionally larger quantities of the first mixture should be taken. For the lime treatment use only 11½ ounces of soil to one of lime, instead of 7¾ pounds, as in the case of fertilizers. Cowpea vines and manure, being used in even greater quantity than the lime, require a still further reduction of the amount of soil in the first mixture, i. e., 4 ounces of soil to one of cowpea vines and 1½ ounces of soil to one of manure. One ounce of each of these mixtures when added to 5 pounds of soil will supply lime at the rate of one ton, cowpea vines, 2½ tons, and manure, 5 tons per acre.

After the fertilizers have been added to the soil, it is allowed to remain in pans or other suitable receptacles for several days, being moistened occasionally with rain-water or water from melted ice, and frequently stirred, so that the fertilizers may become thoroughly distributed. At the end of this time the soil in each pan is moistened again with water, which is ad ed until the soil is in the most favorable condition for plant growth. This varies with different soils, but with a little experience the operator can judge it rather accurately. It is important that the water used in moistening the soil be rain-water, as water from springs, wells or streams may contain mineral matter that would affect the plants, and thus vitiate the results of the tests. The soil in each pan is then divided into five nearly equal parts, and each part is placed in a wire pot, care being taken to press the soil well into the bottom and sides of the pot. The pot should be filled to within about one-half inch of the top. After filling, the soil which projects through the meshes of the wire is carefully brushed off and the pots are then ready for paraffing and planting. The pots are dipped, bottom down, into hot paraffin until an impervious layer is formed over the lower part of the pot, connecting with the rim around the top. In coating the pot, the paraffin is kept at an even temperature and the pot is dipped and quickly removed to allow the paraffin to harden, when it is dipped again, and so on until the coating has the proper thickness, about one-sixteenth of an inch.

Subsequent details of the experiment.

One or two days before the time of planting, a sufficient quantity of wheat is placed between moist cloths, covered with wet sand, and placed in a favorable place for germination. From these sprouted wheat grains those of uniform size and about the same stage of development are selected, six being planted in a row, and to the same depth in each pot. The surface of the soil is now covered to a depth of about one-fourth inch with clean, dry sand. The pots are then placed where they will be under as favorable conditions of light, temperature and moisture as possible, care being taken to keep the pots of each set together.

The pots should be watered at frequent intervals during the growth of the plants, care being taken not to allow them to become too dry nor to make them too wet. The watering is most effectively done by means of a spray or atomizer. As a guide to the amount of water required by the pots, it is a wise precaution to weigh and record the weight of some of them when they are paraffined and planted, at which time the moisture content of the soil is favorable. By weighing these pots at intervals during the tests, the amount of water necessary to bring the soil to a favorable condition can be ascertained, and an equal amount added to all baskets that show an equal growth. At the end of fifteen or twenty days, a comparison of the growth of the plants will enable one to estimate the value of the different fertilizers. (Fig. 646.)

It should be borne in mind that this is a method not for the study of the requirements of plants, but for the study of the fertilizer requirements of soils, in which the plant is used as an indicator. It is, therefore, not necessary to grow the plants to maturity; in fact, it would not be possible to do so successfully in the small quantity of soil used. When differences occur as a result of the fertilizer, they manifest themselves almost from the beginning of plant growth, and it is not necessary or advisable to grow the plants for periods exceeding twenty or twenty-five days from the date of planting the seed. All conditions for plant growth, except the fertilizer applications, should be equal for all treatments, so that the variations in growth may be attributed solely to the fertilizers applied. A mean temperature of about 70° F., and ranging from 50° to 90°, will prove satisfactory for wheat.

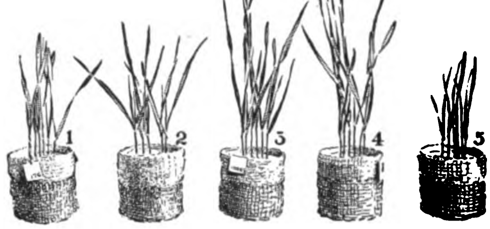


Fig. 646. Wheat plants growing in the wire baskets. No. 1, nitrate of soda; No. 2, nitrate of soda and acid phosphate; No. 3, nitrate of soda, acid phosphate and sulfate of potash; No. 4, stable manure; No. 5, untreated.

Literature.

For more detailed descriptions of this method and the results obtained with it, the reader is referred to Bulletins Nos. 23 *et sequ.* and Circulars Nos. 15, 16, 17 and 18 of the Bureau of Soils; Farmers' Bulletin No. 257 of the Department of Agriculture; Bulletins Nos. 167 and 168 of the Ohio Experiment Station; Bulletin No. 109 of the Rhode Island Experiment Station.

SOIL AMENDMENTS

By *H. E. Stockbridge*

Soil amendments are those substances, organic or inorganic, that are added to the soil for the purpose of correcting certain defects. The object of the amendment is to ameliorate the natural character of the soil so as to increase its productivity. This change or amelioration is effected by three distinct classes of action: physical, chemical, fungous and bacterial. The effects of any single amendment may involve more than one of these agencies.

Though several of the materials demanding recognition as soil amendments possess direct plant-food value, this property is outside the limits of the present consideration. It is permissible here to consider them only in their character as amendments to the soil.

Lime.

The agricultural value of lime has been recognized from a very early date. Except in its immediate relations to bacterial action, little has been added to our knowledge of its properties since the time of Thaer. Present methods of culture and fertilizing make the practical value of lime dependent almost entirely on its action as an amendment. [This subject is fully discussed in the succeeding article.]

Marl.

In many respects marl is similar in action to lime. Its active ingredient is calcium carbonate, of which it may contain over 90 per cent. The influence of marl is chiefly physical, and is due to the property of carbonate of lime of rendering light, porous, leachy soils more compact and retentive. It is a natural amendment for sandy soils, and they are often quite transformed by the physical change produced.

The marl deposits known as "green-sand" contain considerable quantities of potash and phosphoric acid that give it a recognized fertilizing value. Marls vary so greatly in composition that rules for use are suggestive only. About twice the application of lime, that would be made under similar conditions, may be suggested as a reasonable average. The material requires no preliminary treatment, other than mere drying by exposure to the air.

Chalk.

This substance is a more or less pure carbonate of lime. Its character as an amendment is essentially that of marl; indeed, many deposits of "chalk" are simply light colored marl. Such deposits are of very common occurrence in England. The Rothamsted Experiment Station is located directly over such a formation.

Gypsum, or "land-plaster."

This natural sulfate of lime has probably been used longer and more extensively as an application for increasing the productiveness of soils than any other mineral substance. Its present use is due almost entirely to its action as a soil amendment. This action is chemical, and consists chiefly in the substitution of its calcium for the potash in different soil compounds. The potash locked up in the soil in a form unavailable to plants is thus released to enter more available combinations. Its benefits are most marked when clover or other legume is the crop following its application. The legume is able to supply its own demands for nitrogen by extraction from the air. It therefore easily satisfies its entire food requirements by the addition of the liberated potash. Its other necessities are met by most soils. It secures for itself all the nitrogen needed to go with the supply of potash liberated by the gypsum and thus makes exceptional growth.

Gypsum is a specific amendment for the "black alkali" lands of the arid West. The sterile condition of these lands, which exist in considerable areas, is due to the presence of an excess of sodium carbonate, which accumulates on the surface because of the lack of rains and percolation. Gypsum reacts on the carbonate to form the less harmful sodium sulfate and calcium carbonate. In the presence of an excess of free carbonic acid in the soil, particularly through the decomposition of large masses of vegetation, some gypsum may be converted into carbonate of lime, and exert, in a slight degree, the properties already mentioned as pertaining to this substance.

Salt.

This was originally used agriculturally under the supposition that it possessed direct fertilizing value. It possesses a solvent action on soil constituents, particularly on phosphates. This property, however, can not adequately explain the occasional marked benefits resulting from small applications of salt. Increase in the capillary movement of soil waters is sometimes the true secret of these results. Water containing small quantities of salt in solution moves through the soil more rapidly than other waters. In a given time, therefore, more water passes upward and becomes accessible to the crop. This is the real reason for the generally recognized fact that dry seasons and soils show the greatest benefit from the use of salt.

Kainit.

The action of this material as an amendment is due very largely to its large content of common salt,—about 40 per cent. The special advantages of its use are based on the value of the plant-food supplied—12 to 14 per cent of actual potash—and the specific action of the material as a germicide and insecticide. The price of kainit is fixed solely on the potash it contains, which as a plant-food gives full value for the investment. The salt and amending properties of the material are therefore available without cost. This is by far the cheapest way of securing salt as an amendment.

Certain unproductive soils seem to yield particularly to kainit as a corrective. Considerable areas of such land exist in the central-western states, where they are commonly known as "bogus soils." In the Gulf states, soils of similar character are called "white-bud land." Both are low and inclined to be wet. The former tends toward peat in character, while the latter is usually more clayey. Their unproductiveness is due to imperfect drainage, and they do not yield to ordinary methods of underdrainage. The difficulty lies in the presence of a too high permanent water-table at the unproductive point, which often exists as a sterile spot in the midst of generally productive fields or sections. The Indiana Experiment Station conducted experiments for three years, resulting in a net profit of $55.60 per acre on the average crop of corn from the use of kainit at the rate of one ton per acre as an amendment on these soils. (See "Vegetation" as an amendment, below.)

Muck.

Before the use of concentrated commercial fertilizers became general, muck was one of the most common soil ameliorators. It was used under the supposition that it was an important source of plant-food, as well as an improver of the physical condition of many soils. The latter action is practically the only one justifying its present use, since actual plant-food can nearly always be secured more economically in some other form. The home use of this material, on the farms where it occurs, particularly when its direct use is as a stable absorbent, is a commendable practice. The value of muck as an amendment depends on its content of organic matter derived from partly decayed vegetation, though it usually contains one-half to one per cent of nitrogen.

Muck absorbs about 70 per cent of its own weight of water, besides small quantities of ammonia and other gases. It greatly increases the absorptive power of friable porous soils. Its chief value, therefore, is as an amendment to sandy soils. On the other hand, it is light and porous, because of its vegetable origin, and thus improves the physical condition of tenacious clays.

The quantity of dry muck required for effecting real improvement in the character of the soils to which it is adapted is large. Forty tons per acre is not an excessive application. Its effect, however, is lasting and the total application may be gradually reached through successive seasons.

Vegetation.

The growth of plants exerts material influence on soil character aside from the immediate effect on available fertility. The pulverizing action of roots, the bringing of consumed material from the lower strata to become incorporated with the surface soil, by the decomposition of the plant or its roots and leaves, are accepted facts. The plowing under of crops is one of the oldest methods of soil-improvement. Decay of vegetation results in the incorporation of much vegetable matter with the soil. This organic matter is similar to muck or peat in character and action. Organic acids are important products of this decomposition. Green-manuring crops may thus cause a decided acid condition of soils, resulting in temporary unproductiveness. This result may be expected only when the decay of the green crop plowed under takes place very rapidly, under the influence of a warm humid climate. In the southern states this sour condition of the soil is almost certain to follow the turning under of such crops as cowpeas and velvet beans during the summer. The prevention lies in delaying plowing till the crop is dead and dry in the cooler autumn. Under these conditions "green-manuring" is a misnomer and is seldom really practiced. [Consult the article on green-manures on page 503.]

Some forms of vegetable material are among the most effective applications for correcting certain recognized soil faults. The vegetable matter in animal manures exerts important influence on the physical character of soils. Coarse manure renders compact soils more porous and facilitates drainage. Decomposing manure warms cold soils and makes light soils more retentive. Vegetation possesses essentially these same properties when used without the animal intervention. Soils may be rendered either more retentive of moisture or more perfectly drained by using vegetation of corresponding physical condition. This fact has been utilized for the practical correction of an important soil defect. The conditions were mentioned in connection with the use of kainit as an amendment.

In the experiments made at the Indiana Experiment Station (see "Kainit," preceding) a layer of wheat straw three inches thick was plowed into the soil with extremely satisfactory results. In the South pine straw has been found to be equally effective. Corn, tobacco, cassava and small grains are the crops most seriously injured on these lands. Irish potatoes, on the other hand, seem to thrive fairly well without amendment.

In the experiments cited the different materials used as amendments gave the following comparative results:

	Bu. corn per acre	Tons fodder
Natural soil	28.6	1.39
Wheat straw	48.4	2.30
Kainit, 1 ton per acre	55.8	2.43
Kainit, 1 ton per acre; Lime, 5 tons per acre	52.4	2.48
Lime, 5 tons per acre	25.1	1.48

It is apparent from these figures that straw closely approaches kainit, which as an amendment for these soils stands at the head of the list. On the vast number of farms where wheat, oat or pine straw is a home product, with little commercial value, it furnishes the most economical corrective for this trouble. Its use forms one of the most perfect demonstrations of the possible benefits from a purely physical amendment. The stubble of many crops, as well as all sod, possesses distinct corrective influence on soils with a tendency to excessive compactness or imperfect movement of soil waters.

Wood ashes.

Though the chief agricultural value of this material lies in the plant-food contained, potash and phosphoric acid, ashes form an important amendment for sandy soils. The favor in which they were held by our fathers, as a dressing for such soils, was largely due to this property. They contain about 30 per cent of carbonate of lime; their amending action is, therefore, similar to that of marl. It is important to note that leached ashes, though comparatively deficient in available plant-food, contain practically as much of this active amending constituent as exists in the unleached form. Hence, they exert about the same physical and chemical action on soils as do the rarer and much more costly unleached ashes. The difference in practical agricultural value between the two forms of ashes is not so great as the difference in plant-food content.

Bacterial amendments.

The importance of bacterial action on the productivity of soils is thoroughly established. Nitrification and denitrification are among the most constant influences affecting fertility. The feasibility of increasing the crop-producing power of soils by inoculation is generally recognized. There is reason for believing, however, that increase in actual fertility, mere influence on supply of available plant-food, does not always explain the results of bacterial action. Red clover does not thrive on the fertile lands of the upper Mississippi valley. Alfalfa will not grow on much of the best land in the southern states. Inoculation of these soils with bacteria from soils of localities where these crops thrive, results in inducing the crops to grow well where they otherwise failed. Lack of fertility cannot explain the inability of these soils naturally to produce these crops, since they are specially rich in all plant-food essentials. Yet the bacteria have, in some way, changed the soils from a condition of unproductiveness to one of great productivity. Under such circumstances it seems probable that the bacteria act in some unexplained way as a soil amendment. It is not improbable that other soils and crops owe their mutual adaptations to similar action.

Literature.

Much has been said in regard to the use of soil amendments in recent agricultural literature. It is necessary here to refer only to a few of the publications bearing more specifically on the subject. The following will be found helpful: Boussingault, Die Landwirtschaft, Halle, 1851, humus, salts; California Experiment Station Reports, 1892-4, black alkali, gypsum; Cornell University Experiment Station Bulletin No. 119, humus, vegetation; Experiment Station Record, Vol. XV, pp. 661, 860, lime, marl; Indiana Experiment Station Bulletin No. 57, effects of lime, kainit, vegetation on amending soils having a too high water-table; Landwirtschaftliche Versuchs Stationen, 1904, p. 425, marl, caustic lime, effects on soluble soil phosphates; Lloyd, Science of Agriculture, secondary effects of mineral fertilizers; Rhode Island Experiment Station Bulletin No. 28, Report for 1895, lime; Stockbridge, Rocks and Soils, New York, 1895, humus, kainit, mineral salts, lime, marl, vegetation; Thaer, Rationelle Landwirtschaft, Berlin, 1804, distinction between amendments and plant-food, action of peat, lime, marl, salt, ashes and vegetable matter; Voorhees, Fertilizers, marl, mineral salts; Wolff, Dungerungslehre, Berlin, 1884, mineral amendments.

LIME IN RELATION TO SOIL-IMPROVEMENT

By *H. J. Wheeler*

It was understood by certain writers at least one hundred and fifty years before the Christian era, that lime and wood ashes could be used interchangeably for certain agricultural purposes. The agricultural use of lime in the time of Pliny was apparently confined chiefly to orchards and vineyards. Its use by the Chinese in earlier times is said to have been confined largely to the destruction of insects. A revival of the practice of liming appears to have occurred in France at about the beginning of the seventeenth century, though in England its employment was advocated by several writers during the period from 1523 to 1616.

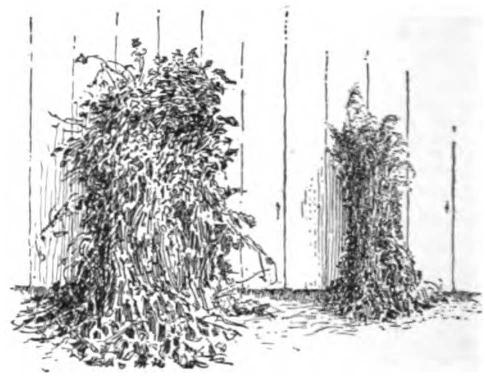


Fig. 647. On the left, limed:—red clover with but very little sorrel. On the right, unlimed:—common sorrel and no clover. Both plots manured with potash and phosphoric acid. No nitrogen had been applied, in either case, for five years.

Either marl, a natural form of carbonate of lime, or slaked lime, has been used extensively in England, Scotland, Wales, Belgium, France and Germany, for several centuries. This accounts for the introduction of the practice of liming into this country by some of the earlier settlers of New York, Pennsylvania and other states, since they were already familiar with its use in the sections of Europe from which they came.

A study of the history of the practice of liming in England and in the United States shows that within the past century there have been periods when the practice became somewhat common, only to be followed by other intervals of neglect. This is doubtless due to the fact that as soon as great benefits from liming are noticed in a given locality the use of it becomes general. Having found it helpful in a high degree, the natural tendency is to carry it to excess, and in consequence of its beneficial influence lasting for ten to thirty years, a successive period of disuse naturally follows. In consequence of this, it would perhaps have been better for certain agricultural regions had lime been less lasting in its effects so that its

Fig. 648. Fertilizer test with oats. Beginning at left, No. 1 was unlimed; No. 2, received calcium chlorid in 1894 and 1895; No. 3, received calcium chlorid in 1894 and 1895, and caustic magnesia in 1897; No. 4, received calcium chlorid in 1894 and 1895, and air-slaked lime in 1897. (R. I. Exp. Sta.)

entire disuse for long periods of years might not have resulted, for then the succeeding generation might not have failed to realize its importance.

The casual reader is at first surprised to find the agricultural literature filled with diverse opinions and different views concerning certain problems relating to liming. In fact, at a time before the actual mineral requirements of plants were understood it came to be an adage that "liming makes rich fathers but poor sons." Fortunately the action of lime is now so well understood, and its varying effect dependent on the variety of plant has been so fully studied, that many of the difficulties in understanding earlier results have now vanished. The well-known action of lime in rendering other substances more easily available to plants, and hence in reducing their quantity in the soil with the natural increase in crop production, explains readily why liming by the father was at the expense of the son. Today it is known to be the best policy to keep the soil in the proper chemical and physical condition by occasional liming, and to supplement the lime with such quantities of the other mineral substances as the crops may require.

How lime benefits.

The benefits of liming may be briefly stated as follows:

(1) Directly, as a substance essential to the growth of agricultural plants. Many soils are in need of lime for other reasons, even though they have enough of it already, in certain combinations, to meet the strict requirements for plant-food.

(2) In promoting the formation of nitric acid and the resulting nitrates from both plant and animal refuse, whether applied artificially or existing naturally in the soil.

(3) In neutralizing acids and acid compounds existing in the soil, and by rendering harmless other toxic compounds which may accompany soil acidity.

(4) Indirectly, in aiding the plant to take more phosphorus, potassium and magnesium from the soil than would be possible in its absence.

(5) In binding certain loose sandy soils. For this purpose it is beneficial only when used in small quantities and preferably as carbonate of lime.

(6) In flocculating clayey soils, thus making their tillage easier, the movement of water and air within them more nearly normal, and in lessening their tendency to "wash."

(7) In lessening injury by insects, but only in specific cases and when used in liberal quantities.

(8) As a means of lessening the injury caused by certain plant diseases, as, for example, in counteracting the tendency to "finger-and-toe" disease in the case of the turnip, cabbage and closely related plants.

(9) In preventing the injury which may result in case the soil contains excessive amounts of magnesium salts in a condition to be readily taken up by plants.

(10) In lessening, in some cases, the tendency to a destruction of nitrates in the soil and the accompanying liberation of free nitrogen.

(11) In influencing favorably on acid soils growth of plants that do not thrive best on such land.

(12) In maintaining certain phosphatic manures in combinations more available to plants than would be possible in the absence of lime. It is recognized that the presence of excessive amounts of lime might have an opposite effect, as, for example, in connection with acid phosphate, dissolved bone-black and dissolved bone.

(13) As a means of counteracting the occasional ill effects from the use of the German potash salts,

Fig. 649. Fertilizer test with spinach. A, sulfate of ammonia; B, nitrate of soda; C, sulfate of ammonia, calcium carbonate; D, sulfate of ammonia, sodium chlorid; E, sulfate of ammonia, sodium sulfate; F, sulfate of ammonia, sodium carbonate; G, sulfate of ammonia, potassium chlorid.

and especially of ammonium chlorid and ammonium sulfate.

(14) In overcoming the tendency of nitrate of soda to cause heavy clay soils to become too compact and hence difficult to till.

Fig. 650. Fertilizer test with barley. Beginning at the left, No. 1, received nothing; No. 2, ammonium chlorid; No. 3, magnesium chlorid; No. 4, ammonium chlorid and calcium carbonate. All of the plots were manured alike with a "complete" manure. (R. I. Exp. Sta.)

(15) In preventing or overcoming the injury due to the presence of certain toxic iron salts.

(16) In improving the conditions necessary to the welfare of certain soil bacteria.

Dangers from liming.

The evil effects of liming are briefly as follows:

(1) In injury to the texture of certain sandy and gravelly soils, if applied even in amounts that are proper for ordinary land, and especially if used in the slaked or caustic condition.

(2) In liberating unduly and consequently wasting other valuable mineral constituents of the soil if used too frequently or in too large quantities.

(3) In promoting a too great and rapid destruction of organic matter if applied too freely and often, especially if the soil is sandy or contains but little decaying vegetable matter.

(4) As a consequence of promoting the development of potato "scab."

(5) After a few years, in causing the decomposition and growing thin of the surface layer in the case of renovated peat or muck soils, unless care is taken to lime frequently to a good depth or to lime the subsoil. The final injury results from the fact that roots do not penetrate freely into the unlimed layers of soil and hence suffer easily from drought after the limed layer becomes thin.

(6) Owing to a direct or indirect effect in lessening the yield of certain varieties of plants that thrive best on very acid soils, such, for example, as watermelon, cranberry, and certain lupines.

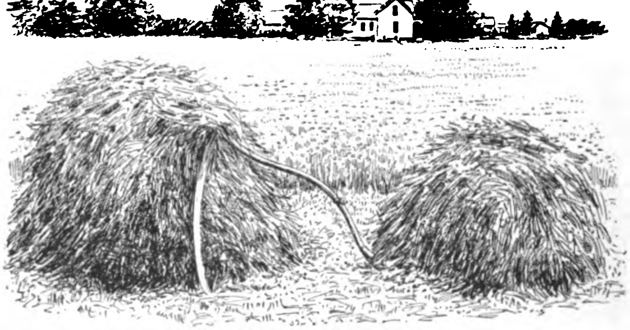


Fig. 651. Grass (first crop). On left, limed; on right, unlimed. Hamilton, R. I. Both plots received "complete" manure.

How to apply lime.

The amounts of slaked lime to use per acre may range from 500 pounds for sandy soils to 5,000 to 6,000 pounds on heavy clays or on soils very rich in acid organic matter. The time of application in a rotation should be shortly preceding the planting of the particular crop or crops most likely to be helped by the lime. In case a rotation is begun with potatoes on a very acid soil, immediate liming is permissible, but in all other cases it should follow rather than precede this crop. In all cases, the seed tubers should be washed with water and then treated with formalin or with corrosive sublimate solution before they are cut for planting. Applications of lime need seldom be made more frequently than once every five to seven years, and if employed at the more frequent interval the amounts should be materially reduced.

Fig. 652. Mangel-Wurzels. On left, limed; on right, unlimed. Both plots manured with potash, phosphoric acid and nitrogen. Moosup valley, R. I.

In spite of existing recommendations to sow lime broadcast on grass lands, it is permissible only on pastures that cannot be plowed, or on pastures and grass lands where re-seeding is not required. The reason is that the chief benefits from liming are dependent on an intimate mixture of the lime with the individual particles of the soil, hence it should be sown after plowing and be mixed with the soil by vigorous harrowing. The harrow should follow immediately on sowing the lime, if slaked or caustic lime is applied. Lime sown in grain drills cannot be expected to exert its full effect the first season, owing to its lack of distribution in the soil. In using slaked or caustic lime, it is well in all cases to apply the material two or more weeks before planting or sowing, and to reharrow just before the planting is done.

What plants to lime.

Some plants are little injured either by lime or by the conditions that exist on acid soils; or, in other words, their range of adaptability is great. The lettuce, beet, onion, cantaloupe, upland cress, and several other kinds of plants cannot thrive where extremely acid conditions prevail. The soy bean, cowpea, lupine, red-top, Rhode Island bent grass watermelon, blackberry, cranberry, and many other species of plants can endure the conditions existing in certain acid soils. Between these classes of agricultural plants most of the others may be grouped, some approaching one and some the other extreme, and all varying in their range limits. [For lists of such plants, refer to Farmers' Bulletin No. 77, United States Department of Agriculture, revised in March, 1905; and to Bulletins and Reports of the Rhode Island Agricultural Experiment Station.]

Tests of soils to ascertain the need of liming.

If soils contain much carbonate of lime they cannot turn a blue litmus paper red; hence, if such a change takes place, it indicates a probable need of lime. Lime may be needed for other reasons, but this must be ascertained by other means. When only slight acidity is indicated, lime may not be needed for most varieties of plants.

The litmus paper test.—To half a cup of soil add water until it is like a thick porridge, and insert the blue litmus paper without handling the end introduced into the soil. After an hour or two remove and rinse only the lower end. If it is intensely reddened, liming is probably desirable. The color is pinkish if much acid vegetable matter is present, but, if not, it may be brick-red.

The ammonia water test.—To a tablespoonful of soil in half a glass of water, add a teaspoonful or more of dilute ammonia water; if the liquid becomes intensely brown after standing for some hours, or especially if it becomes black, the probable presence of acid vegetable matter is indicated.

Kinds of lime.

On soils containing much magnesia, only the purer limes should be used. In any case one or two applications of pure lime should be alternated with those of magnesian lime. According to Loew, there is a definite relationship which should exist between lime and magnesia, but this differs with the variety of plant. A determination of these relationships in a soil can be made only by a chemist.

Common limestone and marble on burning lose carbonic acid gas and become burned or caustic lime. This, on exposure to the air, takes up water and carbonic acid gas and becomes air-slaked lime. It is a mixture of hydrated lime and of carbonate of lime. Burned lime slaked with steam or water produces hydrated or water-slaked lime. Slaked lime on long-continued exposure to the air is changed entirely to carbonate of lime. Chemically it is then the same as ground limestone, only it is usually finer. Burned lime is often prepared from oyster shells. On sandy soils, carbonate of lime is usually preferable to the slaked lime, and on any soil less care is necessitated in its use. For stiff clays and for soils containing large amounts of acid vegetable matter, the slaked or finely ground burned lime is quicker in its action; it probably is also more effective as a liberator of phosphoric acid and other soil constituents.

Land-plaster (gypsum or sulfate of lime) can perform some of the chief offices of lime, excepting in the case of acid soils, though usually it is not so cheap a source of lime as either slaked or burned lime. Land-plaster may change into carbonate of lime if the soil is wet and contains much vegetable matter. In ordinary soils, this action is too slow to meet the requirements, if acidity already exists. Bone and "floats" (phosphate of lime) improve the condition of acid soils, but not so rapidly as basic slag meal. On very acid soils one should not depend on these substances to correct the condition at the outset, though they may maintain it later. What is true of bone, floats and basic slag meal does not hold for the acidulated phosphates, such as dissolved bone-black and acid phosphate. Waste lime from factories should usually be subjected to analysis and should then be used only with the advice of an agricultural chemist. Burned lime may increase two to three times in bulk on slaking, and it usually increases at least one-third in weight. Wood ashes contain about 34 per cent of lime in the form of carbonate of lime, and this is associated with phosphoric acid, magnesia and potash. Such ashes, even if leached, are well adapted to acid soils and to sandy land.

Fig. 653. Fertilizer test with mangel-wurzel beet. Carbonates, limed. Beginning at the left No. 1 received full ration of soda; No. 2, full ration of potash; No. 3, quarter ration each of soda and potash, and No. 4, full ration of soda and quarter ration of potash. (Rhode Island Experiment Station.)

Literature.

A few publications have been selected: A. Dickson, Husbandry of the Ancients (1807), 1, 330; Ruffin, An Essay on Calcareous Manures (1853); Loudon, Encyclopedia of Agriculture, Sixth Edition (1869), 26, 161; Hilgard, Journal American Chemical Society, 16 (1894), 43; Heinrich, Mergel und Mergeln (1896); A. Orth, Kalk und Mergel, Arbeiten d. Deut. Landw. Gesell., No. 5 (1896); Storer, Agriculture (1897), 521; W. Frear, The Use of Lime upon Pennsylvania Soils (1900), Penna. Dept. Agri., Bulletin No. 61; Hilgard, Tenth United States Census; Detmar, Landw. Vers. Sta. 14, 277; Schulze's Lehrbuch d. Chemie f. Landwirthe, Fourth Edition, 588.

Fig. 654. Fertilizer test with English or flat turnips. Chlorids, limed. Beginning at the left, No. 1 received full ration of soda; No. 2, full ration of potash; No. 3, quarter ration each of soda and potash, and No. 4, full ration of soda and quarter ration of potash. (Rhode Island Experiment Station.)

PRACTICAL ADVICE ON THE USE OF COMMERCIAL FERTILIZERS

By *E. B. Voorhees*

It has been very clearly demonstrated that the valuable constituents of plant-food that are liable to be lost from soils, either through leaching or removal of crops, are confined to the three elements, nitrogen, phosphorus and potassium; therefore, in order to add actual plant-food, a fertilizer must contain one or more of these essential elements. It does not follow, however, that applications of other substances that do not contain any one of these constituents are of no value; their value lies not in furnishing the crop with the lacking element directly, but in so amending and improving the conditions of the soil as to make it possible for the plant to secure one or more of these three constituents. For example, the application of lime, while seldom necessary as a direct fertilizer, is a very important addition from the amendment standpoint. The same is true of certain forms of vegetable matter, which may not contain any constituent element, but which by their addition to soils improve physical character and influence the soil to retain moisture in a greater degree. Therefore the fertilizer farmer, in the purchase of his supplies, buys really one or more of these constituent elements; and, inasmuch as they are contained in different natural products, it is possible for him to reduce their cost by securing them in materials that are highly concentrated, and to insure greater efficiency by purchasing the materials containing the constituents in their most available forms. This method is called the purchase of "simples," or ingredients that make up what are known as mixed fertilizers. The advantage of this method, aside from the question of economy of purchase, is that it enables the user to adjust the kind and form of the constituent to the needs of the plant. This principle applies more particularly in the case of nitrogen: if a soluble form is used previous to the time when the plant is able to take it up, there is danger of its being lost by leaching into the lower layers or drains; and if organic forms are used in large quantities, there is the further danger of loss due to the changes that must take place before the plant can use it, as it has been shown that plants take up their nitrogen in a soluble condition, and largely in the form of a nitrate (page 322). In the case of the minerals, the danger of loss is not great, nor is the matter of the form of the constituent so important as in the case of nitrogen; it is here rather a question of an abundance of food than of specific forms, though in the case of quick-growing crops it is essential that the phosphatic materials shall be in available forms. [Further advice on fertilizer practice will be found on pages 472–477.]

The principles underlying fertilizing.

The modern fertilizer farmer recognizes in his work two distinct principles: first, that there must be an abundance or a sufficient excess in the soil of all of the essential elements, nitrogen, phosphoric acid and potash; and second, that crops must be classified into three distinct groups in order that the greatest economy in the use of fertilizers may be attained.

The necessity for the excess of plant-food is due to the fact that unless such is the case, there may come periods in the growth of the plant, due either to an excess or deficiency of moisture, or to too low or too high temperatures, when the plant is unable to appropriate food; and unless there is an excess, so that the plant is enabled to secure more than its normal needs during favorable periods of growth, there will be a deficiency in crop growth. With the abundance, a larger appropriation of food will take place, and the deficiencies in growth, due to unfavorable periods, are made up. In the fertilizing of market-garden crops, particularly, the applications of all kinds of plant-food are excessive so far as the question of actual amounts needed is concerned.

In reference to the proportions of the different constituent elements, it may be said that it is not so much a question of proportion as it is a question of sufficiency, though there is danger of wasteful applications, particularly of nitrogen, unless some reasonable basis for adjustment is followed, or unless the effect of different forms of nitrogenous constituents is understood, and fractional applications made. There is ordinarily no material loss of the mineral elements, and their accumulation in the soil has not been found to be a detriment, but rather an advantage; and because of the lower cost of the minerals, the excessive application is much safer than to limit the amounts because of supposed economy.

The three classes.—The second point that has been found to be of great importance is, that what may be termed "excessive applications" cannot be economically made without regard to the kind of crop grown, for, though the yield may be proportionally increased, the value of the increase in the one case will not warrant so large an application as in another, while in another case the constituents may be wasted because not needed by the crop. In other words, crops may be divided into three classes: (1) those of high commercial value; (2) those of low value; and (3) those that secure nitrogen from the air. The first class includes all market-garden crops, fruits, berries and the like; the second includes cereal grains and hay, and like crops; the third, the legumes, which do not need to be fertilized with nitrogen (included also in 1 and 2).


Fig. 655. Corn. Fertilizer used exclusively.

The crops of high commercial value, as a rule, mature in a short time, are materially affected in their quality by the lack of an abundance of available food in the soil, and when removed from the soil carry away a relatively small amount of the fertility elements; hence the returns per unit of plant-food applied are relatively large. In the case of the crops of low commercial value, their period of growth is much longer and the quality is not so largely influenced by lack of an excess of available food, while, when removed from the farm, they carry away a relatively large proportion of the constituent elements, and hence the returns per unit of plant-food applied are very much less. In the case of the third group, the crops are enabled to get their atmospheric nitrogen in proportion as they are well supplied with mineral food. In the first case, therefore, a large expenditure for fertilizers may cause a very large increase in yield, and a profitable return from their use; in the second class, a very large expenditure for fertilizers may be followed by a proportionate increase in yield, but could not give a large profit on the investment in fertilizers. It does not follow, however, that very large applications may not be desirable in the building up of soil, though the returns would be less than in the case of the other crops, and be distributed throughout a longer period of time.

Systems of fertilizing.

This question of the fertilizer requirements of crops and possible returns from their use, has led to a system of fertilization that is highly commendable, and in many lines of practice the two methods of fertilization indicated may be combined with very great advantage. For example, crops such as potatoes, tomatoes, or others of high commercial value, may have a place in the rotation with corn, wheat and hay. The modern fertilizer farmer then makes his excessive application on the money crop, in order to guarantee a large growth should other conditions be favorable; and the remainder of the crops in the rotation, of low commercial value, are influenced in their growth by the residues from the application made to the money crop. Thus the direct fertilization of the crops of low commercial value may be very materially reduced, indirectly making the money crop, which, because of the large increase in yield, has already paid for the fertilizer applied, and left a profit, pay for the fertilizers that cause a profit-increase in the growth of the other crops.

Fig. 656. Timothy. Fertilizers used exclusively.

With these principles clearly understood, it will be seen that the variations in the kind and quantity of fertilizers used, as well as their time of application, are influenced by the character of the crop, the period of rapid growth, and the objects of its growth,—whether it shall be harvested in its green state or whether it is allowed to mature. Take, for example, a crop of cabbage, tomatoes, celery or early beets: it has been demonstrated by careful investigations that these plants require very liberal applications of nitrogen in order that maximum returns may be secured, and, while belonging to the crops of high commercial value, they differ from potatoes, asparagus, fruits and the like, which are more especially influenced by an abundance of the mineral elements, in the fact that they can utilize to fuller advantage the nitrogen in less soluble forms.

Fertilizer formulas.

In the making up of formulas for these specialized crops, the question of nitrogen becomes of the first importance. Practical growers now use as their initial application what may be regarded as a basic formula, one containing a high content of all of the three essential constituents, in immediately available forms, these being applied in such quantity as to satisfy any possible demands of the crop for mineral elements, but providing less nitrogen than the crops can fully utilize. The nitrogen required in excess is applied in the nitrate form during the period of growth, thus satisfying all demands for food, and in such a way as to enable the plant to make use of it most economically in the production of first quality products. In the case of celery, it has been shown that when 1,000 pounds of a basic fertilizer containing nitrogen 4.5 per cent, available phosphoric acid 8 per cent, potash 7.5 per cent, has been applied when the plants were set, with an application of 400 to 600 pounds of nitrate of

Fig. 657. Modern methods of fertilizing sweet-potatoes. Area one-tenth acre. Applied 61¼ lbs. acid phosphate; 20 lbs. nitrate of soda. Yield, 13¾ baskets No. 1 grade; 10 baskets No. 2 grade; 13 baskets No. 3 grade. Rate, 367 baskets per acre (⅝ peach baskets). (J. W. Killen, Felton, Delaware.)

soda per acre in two or three fractional dressings, the yield has been largely increased, and the selling price of the crop grown with the maximum amount of food more than doubled, making an increased value of crop of $150 to $250 per acre. Naturally, the amount of nitrate of soda to be applied, and the time the applications should be made, are influenced by the character of the season: it will require heavier fertilizing in a wet season than in a dry season, because of the greater liability of loss in the first instance.

Fig. 658. Modern methods of fertilizing sweet-potatoes. Area one-tenth acre. Nothing applied. Yield, 10½ baskets No. 1 grade; 9 baskets No. 2 grade; 6 baskets No. 3 grade. Rate, 225 baskets per acre (⅝ peach baskets). (J. W. Killen, Felton, Delaware.)

It may, therefore, be regarded as a safe rule in the growing of such market-garden crops as early tomatoes, early table beets, early turnips, early cabbage, muskmelons, cucumbers, celery, onions, peppers and early potatoes, that a formula as indicated, and made up, for example, as follows:—

	Pounds
Nitrate of soda	50
Sulfate of ammonia	100
Dried blood	150
Acid phosphate	550
Muriate of potash	150

may be applied at the rate of 1,000 pounds per acre, at the time of setting the plants, or sowing the seed, to be followed by fractional applications of nitrate of soda at the rate of 100 to 200 pounds in each application, two or three times during the season. Of course, it is not necessary for maximum growth that the applications should be made in this way, but if the greatest economy in the use of the materials is to be made, then such practice is preferable.

When potatoes or tomatoes are the money crops in a rotation with wheat, hay and corn, the same basic formula may be used, and at the same rate, though there will be no necessity for additional applications of nitrogen, and residues of constituents left after the potato crop is removed will usually be sufficient to guarantee a good crop of hay or wheat. When the land is left for the hay crops three or four years, top-dressings of a fertilizer rich in nitrates have been found most advantageous. Formulas for these may be made up to contain nitrogen 8 per cent, available phosphoric acid 3 per cent, potash 5 per cent, which would be secured from the following mixture:

	Pounds
Nitrate of soda	500
Ground bone	200
Acid phosphate	200
Muriate of potash	100

An application of 200 to 300 pounds per acre of this mixture will guarantee an abundance of available food at the time that the plant is in greatest need of it. If, in the use of this rotation, yard manure is available, it should be applied previous to planting corn, and would be sufficient to supply an abundance of the elements for this crop.

In the case of fruits, the necessity for quickly available food is not usually apparent, even on medium soils, until the trees are in full bearing. Hence, in order to guarantee a sufficient wood growth, a formula containing a relatively high content of the minerals, and of nitrogen in slowly available forms, as in bone, may be used to advantage, preferably on light land. One made up of ground bone 250 pounds, acid phosphate 450 pounds, muriate of potash 300 pounds, will furnish the constituents in good forms. On heavier land, a mixture of three parts of ground bone

Fig. 659. Modern methods of fertilizing sweet-potatoes. Area one-tenth acre. Applied 61¼ lbs. acid phosphate; 20 lbs. nitrate of soda; 12 lbs. muriate of potash. Yield, 26 baskets No. 1 grade; 12½ baskets No. 2 grade; 11 baskets No. 3 grade. Rate, 490 baskets per acre (⅝ peach baskets). (J. W. Killen, Felton, Delaware.)

and two of muriate of potash would possibly be quite as useful. The application of these mixtures, varying in amount from 300 to 500 pounds per year, will usually insure a continuous and normal growth of tree. When trees are in full bearing, additional nitrogen may be required, in which case it may be secured from yard manure, or by the plowing down of green crops, or by the early spring application of light top dressings, 100 to 200 pounds per acre, of nitrate of soda.

For legumes, a basic formula made up of ground bone 150 pounds, acid phosphate 600 pounds, muriate of potash 250 pounds, applied at the rate of 200 to 300 pounds per acre, would be sufficient to supply the mineral needs of red clover, alfalfa and vetches, and enable the plant to exercise its function of securing its nitrogen from the air; in the case of summer legumes, as the cowpea and soy bean, the application may be increased by at least one-half, as these plants must secure the entire amount of food needed for their growth and development during a short period. In the growing of peas and beans for the cannery, or for early market, the fact that the crop is a legume should be largely ignored, and the fertilizing made the same as for other market-garden crops, because when grown for these purposes the crop must be largely made before soil conditions are favorable for the activities which permit of the appropriation of atmospheric nitrogen.

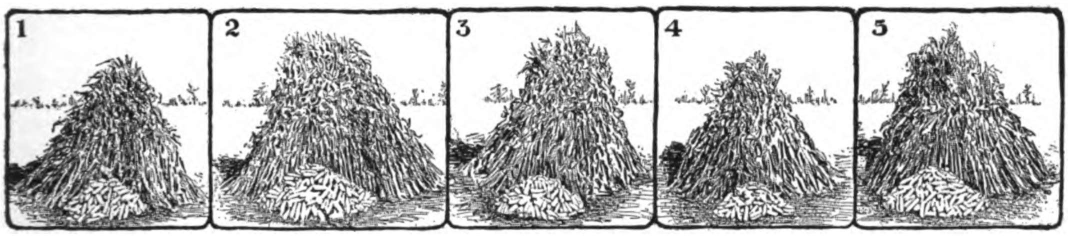


Fig. 660. The effect of a particular fertilizer on soil fertility. No. 1 received no fertilizer; No. 4 received phosphoric acid and nitrogen. This comparison shows no increase from these fertilizers. When potash was used either with phosphoric acid or nitrogen, or both, as in Nos. 2, 3, 5, a large increase was secured. This soil required neither phosphoric acid nor nitrogen, but was very deficient in potash.

General grain rotations.

When no money crop is introduced into the rotation, such as potatoes or tomatoes, and only cereals and hay are grown, as in a rotation consisting of corn, oats, wheat and clover, the fertilizer applications should be more carefully adjusted to the individual requirements of the different plants, though owing to the low commercial value of these crops, financial returns proportionate to those secured from the fertilizing of the others mentioned cannot be expected; however, the applications should be sufficiently liberal to guarantee a maximum crop. In the case of wheat and grass, top-dressings of nitrate in spring will prove advantageous and more economical than if large proportions of nitrogen are contained in the formula used at time of seeding. In a general way, fertilizers for oats should consist chiefly of nitrates and soluble phosphates, as these provide the available constituents likely to be deficient in soils early in spring, when this crop must make a rapid growth if maximum crops are to be secured. Fertilizers for corn should be rich in minerals in any case, and when grown on raw ground, as distinguished from sod, should also be well supplied with nitrogen in organic forms. A good clover sod on good soils will usually furnish sufficient nitrogen, which, under good seasonal conditions, will decay rapidly enough to supply the needs for this element. For wheat and rye, formulas rich in phosphates are desirable, as the need for phosphates in early fall growth is apparently greater than for potash, and an excess of nitrogen would be liable to be wasted, or, if not, to cause too large a growth of top in the fall.

Forage crops.

These require somewhat different treatment from the same crops grown for their grain, as the object is to secure the largest yield of succulent food. Therefore, such an abundance of available food must be supplied as to insure, as far as possible, not only a continuous growth, but one in which the proportion of forage is greater than for the grain crop. This may be accomplished by increasing the proportion of available nitrogen in the formulas used for the same crops when the purpose is the matured grain.

Fertilizer formulas and guarantees.

Probably more than nine-tenths of the fertilizers used in this country are purchased in the form of mixtures containing all three of the essential constituents, nitrogen, phosphorus and potassium. The various brands are prepared from formulas designed to be especially suitable for different crops and soils. This method of purchase saves labor and thought on the part of the farmer, but the cost of the constituents is greater than if the fertilizer materials are bought and home-mixed; besides, in the mixtures, the farmer does not always obtain such proportions of the constituents as are best adapted to his conditions. These mixed fertilizers, as a rule, are, and should always be, accompanied by a statement of guaranteed composition. This is very essential, because purchasers are unable to tell, by mere visual inspection, what kinds and proportions of fertilizing materials have entered into the mixture. In many states the laws require that the source of the materials also shall be distinctly stated, in order to insure the use of good products, as the mixing permits the disguising of poor forms, especially of those containing the element nitrogen.

Guarantees, however, sometimes confuse the purchaser, because the method of stating the guarantee is such as to mislead, provided he does not understand the meaning of the terms, or is unable to convert the percentages into their equivalents. It is entirely legitimate, when there are no laws forbidding, for the manufacturer to guarantee ammonia, instead of nitrogen; bone phosphate, instead of phosphoric acid; and sulfate of potash, instead of actual potash. The statement of the guarantee of the constituents in combination increases the percentage, thus leading ignorant purchasers to think that they are obtaining a larger percentage of the constituents than is really the case.

In the case of raw materials, a guarantee based on the purity of the chemical salts is very frequently used. That is, a substance when pure contains 100 per cent of the specific salt, and the guarantee which accompanies this product is merely a statement that indicates its purity. For example, when nitrate of soda is guaranteed to contain 95 per cent nitrate, it means that it is 95 per cent pure nitrate, or that 5 per cent of the total substance consists of impurities. The same is true in the case of sulfate of ammonia, sulfate of potash, muriate of potash, and other potash salts that may be offered. In order that the farmer may have a simple method of determining the actual content of the constituents, however guaranteed, the following tables are given to show the terms that are used, their equivalent of actual elements, and the factors to use in converting the one into the other:

To convert the guarantee of			Multiply by
Ammonia	into an equivalent of	Nitrogen	0.8235
Nitrogen		Ammonia	1.214
Nitrate of soda		Nitrogen	0.1647
Bone phosphate		Phosphoric acid	0.458
Phosphoric acid		Bone phosphate	2.183
Muriate of potash		Actual potash	0.632
Actual potash		Muriate of potash	1.583
Sulfate of potash		Actual potash	0.54
Actual potash		Sulfate of potash	1.85

The following tables show the methods of stating guarantees on the basis of purity, in the case of many raw materials, and the equivalent percentage on the basis of actual constituents:

RAW MATERIALS.

Guarantee on basis of purity:

Nitrate of soda 95 per cent, or containing 95 per cent pure nitrate.

Muriate of potash 80 per cent, or containing 80 per cent pure muriate.

Sulfate of potash 98 per cent, or containing 98 per cent pure sulfate.

Kainit 25 per cent, or containing 25 per cent pure sulfate.

Guarantee on basis of actual constituents:

Nitrate of soda, total nitrogen	15.64 per cent.
Muriate of potash, actual potash	50.50 per cent.
Sulfate of potash, actual potash	53.00 per cent.
Kainit, actual potash	13.50 per cent.

The following illustration shows a guarantee of the same mixed fertilizer, on the basis of equivalents in combination, and on the basis of actual constituents:

MIXED FERTILIZERS.

Guarantee on basis of equivalents in combination:

Nitrogen (equivalent to ammonia), 2 to 3 per cent.

Available phosphoric acid (equivalent to bone phosphate of lime), 16 to 20 per cent.

Potash (equivalent to sulfate of potash), 6 to 8 per cent.

Guarantee on basis of actual constituents:

Nitrogen (total)	1.65 to 2.50 per cent.
Phosphoric acid (available)	7.00 to 9.00 per cent.
Potash (actual).	3.25 to 4.25 per cent.

It will be observed that the guarantee in the one case means the same as in the other. Different methods of stating guarantees should not mislead those who will familiarize themselves with the terms used, and with the conversion factors.

In the case of the mixed fertilizers, the percentage of the constituent elements that are given on the basis of equivalents represents the amounts when they exist in combination with other elements, viz., nitrogen, as ammonia; phosphoric acid, as bone phosphate; and potash, as sulfate.

Commercial valuations.

In order that farmers may have a basis for comparing the commercial values of brands of different

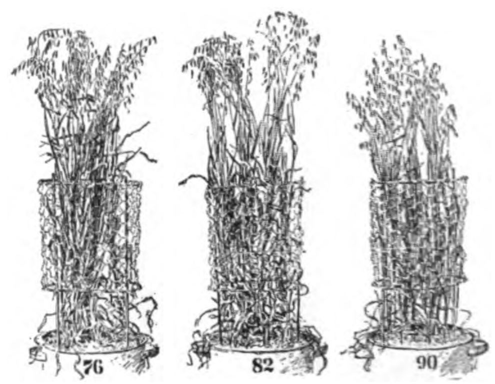


Fig. 661. Showing large crops of oats. Pot 76, soil from Kansas; pot 82, soil from Missouri; pot 90, soil from Wisconsin. To be contrasted with Fig. 662. These two sets of cultures were grown under the same conditions of moisture, sunshine, temperature and tillage. The two illustrations show how the soil itself determines the yield when other conditions are equal.

percentage composition, the various state boards of agriculture or experiment stations, charged with the inspection of fertilizers, usually adopt what is called "a schedule of trade values," which, applied to the various constituents, represents what the constituents in their unmixed state would cost, if purchased in that form, in large lots at the factory. In fixing these values, it is assumed that at points of supply, that is, from jobbers or brokers, the cost of a pound of nitrogen, phosphoric acid or potash, in the various forms, would be practically the same for all manufacturers. The values are secured by averaging the wholesale prices per ton of all the various fertilizer supplies for the six months preceding March 1; to these wholesale prices is added a certain sum sufficient to cover expenses of handling, usually 20 per cent, and then calculating from this price per ton the cost per pound of the ingredients in the various materials. For example, suppose that the average price of acid phosphate, containing 14 per cent of "available," is $10.50 per ton for the six months. To this price is added 20 per cent, or $2.10, which would make the wholesale price at factory $12.60 per ton. Each ton, which costs $12.60, contains 280 pounds of "available" phosphoric acid; or the phosphoric acid costs 4.5 cents per pound, which is then fixed as the trade value.

SCHEDULE OF TRADE VALUES FOR 1906.

	Cents per pound
Nitrogen, in nitrates	16.5
Nitrogen, in ammonia salts	17.5
Organic nitrogen, in dried and fine-ground fish, meat and blood, and in mixed fertilizers	18.5
Organic nitrogen, in fine-ground bone and tankage	18.0
Organic nitrogen, in coarse bone and tankage	13.0
Phosphoric acid, soluble in water	4.5
Phosphoric acid, soluble in ammonium citrate	4.0
Phosphoric acid, insoluble in fine bone and tankage	4.0
Phosphoric acid, insoluble in coarse bone and tankage	3.0
Phosphoric acid, insoluble in mixed fertilizers	2.0
Phosphoric acid, insoluble in fine-ground fish, cottonseed meal, castor pomace and wood ashes	4.0
Potash, as muriate	4.25
Potash, as sulfate, and in forms free from muriates (or chlorids)	5.0

The valuation obtained by the use of this schedule is merely a guide as to the commercial value, and is not intended to indicate even a possible agricultural value. This point needs to be emphasized. The agricultural value of a fertilizer is a variable factor, depending both on the availability of the constituents in it and on the value of the increased crop produced from its use. [If the reader wants tables of the fertilizer constituents of various substances, he will find thirty pages of them in Roberts' "Fertility of the Land," and shorter lists in various books and bulletins.]

How to figure the trade value of a fertilizer.

It is assumed that the mixed fertilizer is guaranteed to contain

Ammonia	4 per cent
Available phosphoric acid	8 per cent
Total phosphoric acid	9 per cent
Potash	6 per cent

and that the nitrogen exists in three forms, as nitrate, as ammonia, and as organic; the phosphoric acid in three forms, soluble, reverted and insoluble; and potash in two forms, sulfate and muriate. The 4 per cent ammonia would be equivalent to 3.28 per cent nitrogen, 1 per cent of which is nitrate-nitrogen, ½ per cent sulfate of ammonia-nitrogen, and 1.78 per cent is derived from organic forms. Of the total phosphoric acid, 6 per cent is soluble, 2 per cent reverted, and 1 per cent is insoluble; of the total potash, 3 per cent is derived from muriate and 3 per cent from sulfate.

The first column in Table A shows the percentage of the constituents contained, which, multiplied by 20, gives the pounds per ton in the second column, which, multiplied by the schedule prices per pound, gives the valuation per ton, as shown in the fourth column.

In the case of ground bone, the guarantee is 4 per cent ammonia and 48 per cent bone phosphate, which are equivalent to 3.28 per cent nitrogen and 22 per cent phosphoric acid. It is assumed that 60 per cent of the material is finer than $\frac{1}{50}$ of an inch, and is regarded as "fine," and 40 per cent is coarser than $\frac{1}{50}$ of an inch, and is regarded as "coarse."

TABLE A.—COMPLETE FERTILIZER.

	1 Per cent or pounds per 100				2 Pounds per ton		3 Value per pound cents		4 Estimated value per ton of each constituent	5 Total estimated value per ton
Nitrogen, as nitrates	1.00	×	20	=	20.0	×	16.5	=	$3 30	
Nitrogen, as ammonia salts	0.50	×	20	=	10.0	×	17.5	=	1 75	
Nitrogen, as organic matter	1.78	×	20	=	35.6	×	18.5	=	6 59	
Total nitrogen	3.28				65.6					$11 64
Phosphoric acid, soluble	6.00	×	20	=	120.0	×	4.5	=	5 40	
Phosphoric acid, reverted	2.00	×	20	=	40.0	×	4.5	=	1 80	
Phosphoric acid, insoluble	1 00	×	20	=	20.0	×	2.0	=	40	
Total phosphoric acid	9.00				180.0					7 60
Potash, as muriate	3.00	×	20	=	60.0	×	4.25	=	2 55	
Potash, as sulfate	3.00	×	20	=	60.0	×	5.0	=	3 00	
Total potash	6.00				120.0					5 55
										$24 79

TABLE B.—GROUND BONE.

	1 Per cent or pounds per 100		2 Per cent of fineness		3 Per cent or pounds per 100				4 Pounds per ton		5 Value per pound, cents		6 Estimated value per ton of each constituent	7 Total estimated value per ton
Nitrogen	3.28	×	60	=	1.97 in fine	×	20	=	39.40	×	18.0	=	$7 09	
	3.28	×	40	=	1.31 in coarse	×	20	=	26.20	×	13.0	=	3 41	
Total . . .					3.28				65.60					$10 50
Phosphoric acid	22.00	×	60	=	13.20 in fine	×	20	=	264.00	×	4.0	=	10 56	
	22.00	×	40	=	8.80 in coarse	×	20	=	176.00	×	3.0	=	5 28	
Total . . .					22.00				440.00					15 84
														$26 34

The first column in Table B shows the percentage, or pounds per hundred, of the constituents, which is multiplied by the percentage of fineness, which gives the percentage or pounds per hundred of fine or coarse in the third column. The calculation is then completed as in complete fertilizers.

Method of application of fertilizers.

In general farming, fertilizers are usually applied with the drill or planter, and with the seed, at time of seeding. Machines are now available for such application, which makes the practice entirely safe, provided too large quantities are not used. The ordinary mixtures for corn and other cereal grains are not, as a rule, so concentrated as to cause any serious injury by this method. For example, in the case of corn-planters, the fertilizer is usually dropped first, lightly covered with soil, then the grain is dropped, thus not bringing the seed directly in contact with the fertilizer. In the case of wheat and rye, such separation of the seed from the fertilizer is not possible, though the danger of injury with the usual applications of 200 to 400 pounds per acre is very remote. When larger quantities are used, or when grass or other fine seeds are sown, it is much better to apply the fertilizer previous to seeding, and thoroughly mix it with the surface soil. This may be accomplished by the ordinary broadcasting machines now on the market; or it may be applied with a grain-drill, which deposits the fertilizer immediately under the surface, and the subsequent harrowing will distribute it and prevent any injury to the seed. In the application of fertilizers for market-garden crops, when the amounts are usually very much greater, both methods are used. In the case of white potatoes, 600 to 800 pounds of the fertilizer may be applied at the time of planting, without injury, provided the mixture does not contain too large a proportion of nitrate or potash salts, though a fertilizer containing as much as 10 per cent of potash may be applied without injuring the germinating power of the seed. This will depend somewhat on the season. If the weather is very dry following the planting, and a dilute solution is not made of the salts, injury may result. Therefore, it is safer to apply a smaller amount with the seed, and the remainder after the crop is planted, either broadcast or drilled in. It is much better, as a rule, to apply the fertilizer on the surface and cultivate it in, than to plow it down, except in the case of fruits and berries.

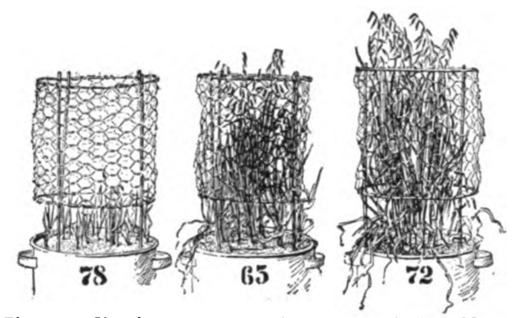


Fig. 662. Showing small crops of oats. 78, soil from Massachusetts; 72, Illinois; 65, California. (See Fig. 661.)

FARM MANURES: THEIR CHARACTERISTICS AND VALUES

By *W. P. Brooks*

In ordinary usage, farm manures, in the sense in which we use the term, may be considered under the following sub-divisions: (1) Barnyard manures: This term is commonly used, at least in New England, to designate manure derived principally from cattle. The term was doubtless originally given because such manure usually accumulated in the barnyard. This is no longer usually the case, but the name is still applied to manure of this character whether it be made in stables, cellars or yards. (2) Stable manure: in ordinary American usage, this term designates manure made principally or altogether from horses. (3) Sheep manure. (4) Hog manure. (5) Poultry manure.

General characteristics of farm manures.

If, for the time being, we exclude poultry manures, since these differ in important particulars from the manures derived from the larger domestic animals, we find that there are certain general considerations affecting the value of manures which apply almost equally to each of the four classes.

The manure derived from each of the larger domestic animals in most cases is composed essentially of three different ingredients: dung, urine and litter. The nature of each of these classes of material must be briefly considered.

(1) *Dung.*—The dung of domestic animals consists of the undigested portions of their food, ground more or less fine according to the nature of the animal, moistened and softened by the addition of different digestive fluids, and, to a slight

extent, admixed with waste tissues of the alimentary canal. The undigested portions of the food found in the dung consist very largely of the woody or fibrous tissues of the food, but the dung that contains these undigested portions is in a much better mechanical condition to act as a manure than the original material, because it has been ground so fine and softened so much that it will decay readily. The dung from domestic animals, although often looked on as the principal part of the manure, possesses considerably less plant-food constituents than the urine. It varies considerably in composition, and some figures comparing it with urine will be found later in this article. In this place, it suffices to point out in a general way that the dung usually contains about one-third of the total nitrogen of the feces, one-fifth of the total potash, and nearly all of the phosphoric acid. The constituents of the fresh dung are not soluble to any great extent and not in condition to serve immediately as the food of plants. Before its elements become to any great extent available, the dung must undergo decomposition.

(2) *Urine.*—The urine of domestic animals, though composed chiefly of water, contains a variety of the compounds produced as the result of metabolic changes acting on the digested portions of food, and to some extent on the worn-out tissues of the body itself. Urine usually contains about two-thirds of the total nitrogen, four-fifths of the potash and but very little of the phosphoric acid voided by the animal. The nitrogen of the urine of the common domestic animals is found chiefly in the form of two rather complex organic compounds, namely, urea (CH_4N_2O) and hippuric acid ($C_9H_9NO_3$). Urine very readily undergoes complex fermentations, in the course of which the two nitrogen compounds above named are soon converted into ammonia and ammonium carbonate, and these in turn eventually into nitrates. It is well known that nitrogen in the form of ammonia, ammonia compounds or nitrates, is more readily available as food than are urea and hippuric acid, and yet there is strong evidence which supports the view that these compounds may under some circumstances be directly taken up and assimilated by the plant. Even if this is not under all conditions the case, it is an undoubted fact that the constituents of the urine will become available as food for plants under ordinary conditions far more quickly than the constituents found in the dung.

Relative amounts of dung and urine.—The relative amounts of dung and urine vary widely with the different animals and to some extent with the food. Especially is the last condition of importance in the case of the hog. For the cow, the total weight of urine under normal conditions is about twice the weight of the dung. For the horse and the sheep, there is much less difference. The two are usually of substantially equal weight, although the dung not infrequently weighs somewhat more than the urine. For the hog, the variation in relative amounts is so great that any general statements can have little value. As a rule, however, the urine is relatively very abundant.

Composition of dung, urine and drainage liquors.—The serious nature of the loss which the farmer must suffer when he allows any part of the urine of his domestic animals to be lost, or permits the natural drainage from the manure to escape, will be made very apparent by examination of the figures showing the composition of these different classes of materials. The figures presented for dung and urine are taken from Wolff, a German authority, and are the average of a large number of determinations. Perhaps they may not accurately represent similar averages under conditions existing in this country, but the writer has not at hand the data from a sufficient number of American analytical determinations to make the calculation of reliable averages possible.

COMPOSITION OF FRESH EXCREMENT.

One thousand pounds of fresh dung contain :—

	Water	Nitrogen	Phosphoric acid	Alkalies
	Pounds	Pounds	Pounds	Pounds
Horse . .	760	5.0	3.5	3.0
Cow . . .	840	3.0	2.5	1.0
Swine . .	800	6.0	4.5	5.0
Sheep . .	580	7.5	6.0	3.0

One thousand pounds of fresh urine contain :—

	Water	Nitrogen	Phosphoric acid	Alkalies
	Pounds	Pounds	Pounds	Pounds
Horse . .	890	12.0	0.0	15.0
Cow . . .	920	8.0	0.0	14.0
Swine . .	975	3.0	1.25	2.0
Sheep . .	865	14.0	0.5	20.0

The potash of both the dung and the urine is included with lime, magnesia and other elements, to make up the so-called "alkalies." Particular attention is called to the fact that notwithstanding the urine contains relatively much more water than dung, the amounts both of nitrogen and of alkalies in equal quantities by weight are much greater in the former than in the latter.

COMPOSITION OF DRAINAGE LIQUORS.

One thousand pounds contain :—

	Water	Nitrogen	Phosphoric acid	Potash
	Pounds	Pounds	Pounds	Pounds
Drainage from gutter behind milch cows . .	932	9.8	2.4	8.8
Drainage from manure heap . .	820	15.0	1.0	49.0

The figures presented in this last table are based on analyses made at the Hatch Experiment Station, Amherst, Mass. It will be noticed that these liquors are richer both in nitrogen and in potash than the average of farm manures.

(3) *The litter.*—The character and value of manure is very largely affected by the kind and amount of litter used. Litter, while used primarily to afford a comfortable bed and to assist in keeping the animals clean, serves to absorb and retain urine, to absorb gases to some extent, and to dilute the manure, making even distribution easier. The litter may also carry to the manure very considerable amounts of plant-food; and it will improve the manure in its mechanical condition. The constituents of most kinds of litter are in relatively unavailable forms and the material must decompose before its food elements are brought within the reach of the plants.

Various kinds of litter are employed in the different parts of the United States. Among those more commonly available are, straw from the different cereal grains, marsh hay, leaves, corn stover, sawdust and planer shavings, and peat moss. Earth of different kinds, though strictly speaking not litter, is frequently used beneath the animals as a partial or complete substitute therefor and must be here considered.

(*a*) Straw.—The straw of the different grains is one of the most satisfactory materials that can be used for bedding. It has great capacity to absorb urine and has considerable manurial value. The straw of the different grains differs materially in toughness and wearing qualities, but the effect of the different kinds on manure is not materially different. A ton of straw will usually contain about 16 pounds of nitrogen, 4 pounds of phosphoric acid, 26 pounds of potash, and 9 pounds of lime. An average ton of farmyard manure contains about 10 pounds each of nitrogen and potash. A ton of straw, therefore, contains more of these elements than a ton of average manure. It follows then that by the liberal use of straw the proportions of nitrogen and potash in manure by weight will be increased. A cord of strawy manure weighs much less than a cord of clear manure and contains much less plant-food.

(*b*) Marsh hay.—There are two distinct classes of marsh hay in use, namely, salt and fresh. Both kinds have about the same qualities as straw, though somewhat less absorptive. The salt marsh hay does not decay so quickly as straw. There is much variation in the value of hay of these classes for litter, determined chiefly by the species of which it is composed. Fresh marsh hay sometimes contains weed seeds that may prove troublesome. Although the liberal use of either of these kinds of hay as litter will have about the same effect on the composition of the manure as straw, when the latter is employed the manure will generally be preferable.

(*c*) Leaves.—Leaves nave good absorptive properties, but possess a lower manurial value than either straw or marsh hay. When mixed with manure, they decompose rapidly and the constituents of manure when they have been used for litter will become available within a relatively short time.

(*d*) Corn stover.—Although corn stover has such value for food that its use for litter is inexpedient from an economical point of view, it is nevertheless not infrequently used for litter. If well dried, it has good absorptive qualities, but unless shredded or cut it is too coarse to be satisfactory. Its manurial value when well dried is about the same as that of straw.

(*e*) Sawdust and planer shavings.—These materials have relatively little manurial value. If thoroughly dried, however, they are good absorbents. There is a wide-spread prejudice against their use on the ground that the soil is rendered sour. So far as can be ascertained, this peculiar effect has never been clearly demonstrated. Neither sawdust nor shavings will add materially to the plant-food content of manure, but when they are used as litter in moderate amounts, the mechanical condition of the manure is good.

(*f*) Peat moss.—This material is as yet relatively little used in the United States, but when such moss can first be thoroughly dried, its use insures the acme of comfort to the animal and excellent sanitary conditions. It is a good absorbent, being capable of taking up about ten times its weight of water, while straw takes up only about three times its weight. The use of peat moss in fairly liberal amounts would be favorable to the production of an excellent quality of manure.

(*g*) Earth.—Sandy earth, especially if coarse, is a relatively poor absorbent. Fine earth, if first well dried, especially if it contains considerable organic matter, is a fairly good absorbent. The use of such earth beneath or behind the animals in stables is calculated to favor the production of manure of good quality. Such earth is superior to strawy litter according to some of the most recent investigations, since it contains much less highly carbonaceous organic matter. It has been found that the presence of excessive amounts of such matter in manure, as, for example, when straw is abundantly used for bedding, produces conditions which are favorable to a considerable loss of nitrogen (the most valuable element of the manure) in the form of uncombined nitrogen gas.

Conditions affecting the value of manures.

It is a well-known fact that the value of farm manures varies widely. This variation is due to two classes of factors: first, those affecting the quality of the excrements as voided; second, exterior factors.

Factors affecting the quality of excrements.—The composition of the excrements from any single class of animals when voided varies widely. The factors exercising the most marked effect are the food of the animal, its age, the products produced by the animal, and its condition.

(*a*) Food.—Other things being equal, the richer the food of the animal in plant-food constituents, most important among which are nitrogen, phosphoric acid, potash and lime, the more valuable are the excreta for manure. The manure from animals fed largely on straw, corn stover or timothy hay, will be comparatively poor, especially in the valuable element nitrogen, because these foods are poor in nitrogen; while the excreta from animals receiving a liberal quantity of such foods as wheat bran, gluten meal and cottonseed meal will be rich, particularly in nitrogen and phosphoric acid. The excreta from animals fed largely on clover or alfalfa hay will be richer in nitrogen, under otherwise similar conditions, than the excreta from animals fed on timothy hay. Tables issued by many of the Experiment Stations give very full information in regard to the plant-food constituents in different foodstuffs, but to bring out more fully the fact that variation in food must cause a very wide variation in the composition of animal excreta, a table showing the more important plant-food constituents of some of the foods most generally used is herewith presented:

FERTILIZER INGREDIENTS IN FOODSTUFFS.

	Pounds in 100.			
	Water	Nitrogen	Phosphoric acid	Potash
Green fodders:				
Corn fodder	79.	.41	.15	.33
Japanese barnyard millet	75.	.46	.11	.49
Oats	83.	.49	.13	.38
Soy beans	70.	.84	.20	.71
Corn silage	80.	.42	.13	.39
Hay and dry coarse fodders:				
Corn stover	20.	.92	.26	1.22
English hay	15.	1.27	.29	1.50
Rowen	15.	1.70	.46	1.56
Timothy	15.	1.19	.33	1.40
Salt hay	15.	1.06	.23	.65
Millet	15.	1.22	.46	1.61
Red clover	15.	2.01	.41	2.11
Roots and tubers:				
Sugar-beets	87.	.22	.10	.48
Mangel-wurzels	88.	.15	.14	.34
English turnips	90.	.17	.12	.38
Rutabagas	89.	.19	.12	.49
Potatoes	80.	.29	.08	.51
Grains:				
Corn	10.9	1.82	.70	.40
Oats	9.0	2.10	.68	.48
Soy beans	18.3	5.30	1.87	1.99
Flour and meal:				
Corn meal	14.1	1.92	.71	.34
Corn and cob meal	9.0	1.41	.57	.47
By-products:				
Cottonseed meal	8.2	6.70	2.47	1.83
Cleveland linseed meal	8.0	5.83	1.70	1.25
Gluten meal	9.6	6.04	1.43	1.06
Gluten feed	8.2	3.72	.34	.06
Wheat bran	9.9	2.36	2.10	1.40
Wheat middlings	10.2	2.75	1.25	.75

(*b*) The age of the animal.—So long as the animal is making growth, that is, forming new bone and muscle, the elements which enter into this new bone and muscle must be taken out of the food, and the excreta, therefore, are poorer than those of animals similarly fed which have completed their growth. The elements chiefly affected are nitrogen and phosphoric acid, both of which enter largely into the bones, and the nitrogen also into the muscle. The quality of manure made from well-fed mature animals is likely, therefore, to be considerably better than that made from young animals.

(*c*) Product.—Such essential elements of plant-food as are contained in any products for which animals are fed, such as milk or wool, must, of course, come in the last analysis from the food, and accordingly there remains so much the less of these elements to be voided in the excreta. Milk contains considerable nitrogen and phosphoric acid and a moderate amount of potash. Wool fiber contains a large amount of nitrogen, while in the oil or yolk of eggs a large amount of potash is found. The manure from milch cows is likely to be relatively poor in nitrogen and phosphoric acid.

(*d*) The condition of the animal.—If the animal is low in flesh, or in so-called poor condition, it must take from its food the materials necessary to bring the body into a better or well-nourished condition. This change will make necessary the removal from the food of large quantities of protein (rich in nitrogen) and will to just the extent to which this is taken reduce the value of the manure. The excreta from mature animals which are being fattened are richer than those from any other class of farm animals, for fattening mature animals are increasing the weight of the body by additions consisting almost exclusively of fat, and fat contains neither nitrogen, phosphoric acid nor potash in appreciable amounts. The excreta from fattening growing animals, although reduced in value somewhat by the withdrawal of nitrogen and phosphoric acid for the building of bone and muscle above alluded to, are still likely to be relatively rich in plant-food elements, as the food of such animals is usually rich in such elements.

Exterior factors.—The conditions affecting the saving and preservation of the elements of value in the excreta affect the value of manures in far greater degree than do those factors which affect the quality of the excreta as voided. The most important of the factors which have an influence are stable construction and management, the kind and amount of litter or bedding used, the use or non-use of chemical absorbents and the way in which the manure is stored and kept. The object sought always is prevention of all loss of valuable constituents. The chief sources of loss are, (1) through the escape of urine or natural drainage liquors; (2) by exposure to rain and leaching; (3) by fermentation. If the urine or natural drainage liquors be allowed to escape in whole or in part, or if manure be exposed to the leaching action of heavy rains, there will be a great loss both in nitrogen and in potash, for the greater part of these is originally found in the urine. Fermentation, if not properly controlled and its products saved, results in serious loss of nitrogen.

The conservation of manure.

Whatever the method of preserving manure, the objects are to prevent: first, the ammoniacal fermentation; second, the volatilization of ammonia from urine and manure; third, the activity of the denitrifying organisms.

The statements made concerning the causes and the nature of the changes taking place in manure must have clearly indicated the methods that must be adopted to prevent loss while at the same time securing that improvement in mechanical condition which is a consequence of the softening and gradual decay, especially of the litter. Very briefly, we may sum up the whole matter by saying

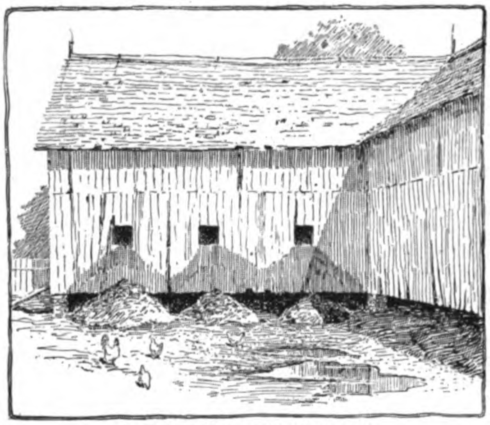


Fig. 663. The waste of manure.

that manure should, if possible, be kept in a water-tight receptacle to prevent loss from drainage; under cover to prevent leaching; compact and moist to prevent too rapid heating; while chemical absorbents may wisely be added to insure against volatilization of ammonia. Manure should be kept compact, moreover, in order to prevent a too large formation of nitrates. The principal part of the nitrogen must enter into combination as nitrates before it is available to the plant, but this change goes on more safely in the soil than in the manure heap. There is danger that if it be allowed to go on too largely in the manure heap, a considerable share of them may be destroyed by the denitrifying organisms that live in the lower parts of the heap. The more nearly manure can be kept under conditions similar to those under which green fodders are kept in a silo, the more certainly will its valuable constituents be conserved.

Stable construction and management.

Stable construction and management are important chiefly because of their bearing on the extent to which the fluid part of the excreta is saved. The figures presented and the statements made must have made it evident that any loss of urine seriously decreases the value of the manure, and yet it is to be feared that to this day there are farmers who act as if they believed such loss to be unimportant. In many of the older stables, much urine was allowed to escape, oftentimes through cracks in the floor on which the animals stood. In other cases, the manure when removed from the stables was thrown into a heap in the open air, where the rains and in some cases the water from the roofs as well soaked through it, carrying away a considerable proportion of its soluble and most valuable constituents. Such stables, and stables where no provision for the protection of the manure has been made, are still far too frequent. (Fig. 663.)

The details of stable construction may, of course, be almost infinitely varied, but no farmer should lose sight of the fact that loss of urine and leaching of the manure should be prevented. To this end, it is necessary, first, that the platform and the gutter behind the animals shall be water-tight. In some of the best stables, the gutter is sloped to an outlet, from which the urine is led into a cistern or tank set to receive it. This plan is infinitely better than to allow the urine to escape, but for many reasons it seems preferable to keep dung and urine together. Neither by itself is a well-balanced manure. Dung is poor both in nitrogen and potash; the urine contains little phosphoric acid. If the two be kept together, the manure suits the average crop better than either dung or urine alone. Moreover, if the urine be separated from the dung, especially in the case of horses, the latter becomes too dry. Manure keeps better and decomposition goes on under better conditions when it is rather moist. As a rule, then, it seems best to use bedding in sufficient quantity so that the dung and urine may be handled together.

The stable should usually be cleaned twice daily. Many of the older barns and some of those of modern construction have cellars underneath into which the manure is thrown. If the cellar is naturally dry and is made water-tight, it is a good place in which to put manure. There is no other way in which the latter can so conveniently and at so little cost for labor be removed from the stable; but placing manure in a cellar underneath the stable in which animals are kept is objectionable on sanitary grounds. Foul odors and gases inevitably find their way from the cellar into the stable in greater or less degree. True, by thorough ventilation of the cellar and by the free use of chemical absorbents, the disadvantages can be in a measure removed. On the whole, however, it is now generally conceded that manure should not be stored underneath stables in which cows or horses are kept. A better plan is to provide a covered pit convenient of access from the stable. The manure is then collected either by use of receivers carried by overhead trolley tracks (Fig. 664) or in wheelbarrows and conveyed directly to the pit. (Fig. 665.) If this plan is followed, the pits should be of such capacity that the manure can be stored for a few weeks at least. Such pits should be water-tight and roofed and the manure in them, if allowed to remain long, should be occasionally leveled and kept both moist and compact. Provided swine are given access to clean sleeping and feeding quarters, there seems to be no practical objection to allowing them to range over the manure, and from the standpoint of the quality of the latter, this plan has much to recommend it. The pit should be so located that effluvia from the manure will not find their way into the stable.

In some cases, manure as it is taken from the stable is dumped directly into vehicles and at once taken to the field. From a sanitary point of view, this plan has much to commend it, but it is an expensive method of handling manure because of the more or less unavoidable interference with the other work of the farm which is necessary in carrying out this plan.

Deep stalls are used in some countries in the stabling of cattle. The deep stall at the beginning of the season is a water-tight pit of moderate size, in which the animal stands. The manger is movable, being raised as the amount of manure beneath the animal increases. The manure is occasionally leveled and litter is very abundantly used. The elements of value in the manure are very perfectly saved under this system, because the urine is all absorbed and the compactness of the manure beneath the animal is such as to prevent fermentation and the losses which often accompany it; but this method would not satisfy American ideas as to the sanitary conditions desirable in the housing of cows and the production of milk. It may be used for fattening stock; and experiments conducted at the Pennsylvania Experiment Station as well as in Europe demonstrate conclusively that the elements of value in the manure are more perfectly saved under this system than under any other.

In the case of animals loose in pens, as, for example, young cattle and sheep, the manure may safely be allowed to accumulate some time, perhaps for the entire winter. If bedding and absorbents are freely used, the animals are kept clean, the urine is entirely absorbed and the continual trampling of the animals keeps the manure so compact that no loss through heating or fermentation occurs, nor, under such circumstances, since there are practically no effluvia from the manure, is the air seriously contaminated.

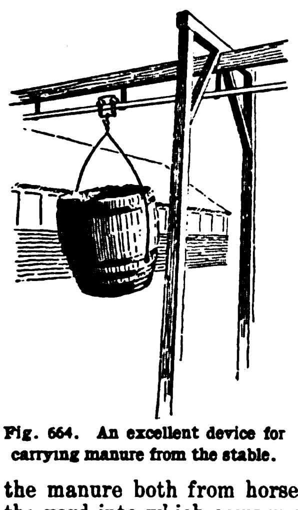


Fig. 664. An excellent device for carrying manure from the stable.

A covered yard for the reception of manure as it is removed from the stables has been strongly recommended in some quarters. The plan advised was to spread the manure both from horses and cows evenly in the yard into which cows were turned for exercise. The roof protects the manure. The trampling of the animals keeps it sufficiently solid to avoid too rapid fermentation. The mixture of the horse and cow manure is rather favorable to the mechanical condition of the resulting product. There can be no doubt that when litter is abundantly used, manure may be very perfectly saved under this system, but it seems doubtful whether the construction and maintenance of so much roof as this system will make necessary is economical. The pit for the storage of manure seems preferable. The mixture of horse and cow manure in the pit, whenever it can be conveniently accomplished, is advisable under the ordinary conditions of the farm. (Fig. 666.)

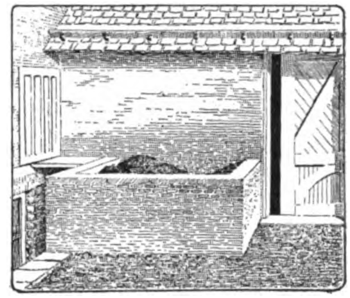


Fig. 665. A neat brick manure pit for a city or town yard.

Kind and amount of litter to use.

As must be evident from the statements which have been made concerning the different materials used as litter, the character and value of manure is largely affected both by the kind and by the quantity employed. The plant-food carried into the manure by the litter is by no means unimportant, and it varies widely with different materials. The table showing composition of some of the more common materials employed will make this point clear.

Composition of Litter.

One ton contains in pounds:—

	Nitrogen	Phosphoric acid	Potash
Wheat straw	9.6	4.4	16.4
Rye straw	11.2	5.1	18.1
Oat straw	14.4	3.6	23.0
Barley straw	11.4	5.0	23.5
Pea straw	20.8	7.0	19.8
Soy bean straw	14.0	5.0	22.0
Buckwheat straw	13.0	7.1	24.2
Millet straw	14.0	3.6	34.0
Marsh hay	17.2	10.6	54.0
Ferns	00.0	7.4	37.2
Leaves	15.0	3.2	6.0

While most kinds of litter carry plant-food to the manure, and while it might, therefore, seem that the greater the quantity used the more valuable the manure, there are considerations which indicate that too free a use of litter is undesirable. In the first place, a very abundant use of litter will make the manure too dry; but, more important, the results of European investigations indicate that the presence in the manure of too large amounts of litter of some kinds, particularly straw, is likely to increase the extent to which nitrates formed in the manure are destroyed and the nitrogen they contain lost in the uncombined form through passing into the air. It is the nitrogen of the urine which is most likely to be affected. In the rapid fermentation of the urine, nitrates are formed. The solid excreta appear to contain organisms likely to decompose these nitrates, leaving the uncombined nitrogen to escape. This nitrate-destroying power of solid excreta is very considerably increased by the addition of straw.

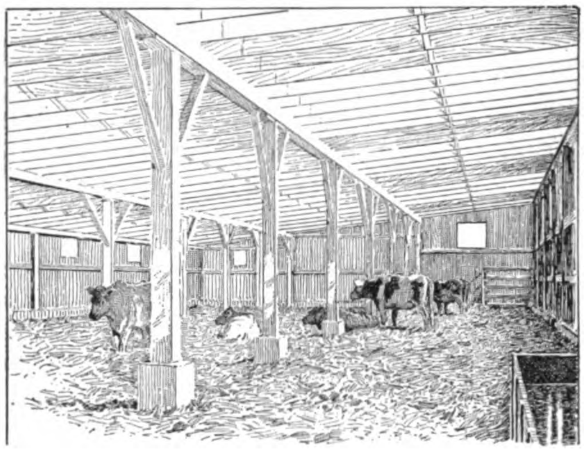


Fig. 666. Covered barnyard.

The use of some straw or material of similar nature is a practical necessity, but the quantity used should be limited to such amount as is essential to secure the requisite comfort and cleanliness of the animal and to absorb the urine.

Chemical absorbents.

It will be more fully explained later that during the fermentation or heating and rotting of the manure, part of its most valuable constituent, nitrogen, is likely to escape into the air in the form of ammonia or ammonium carbonate, both of which are volatile. The proper use of chemical absorbents in the stable may in very large measure prevent this loss and at the same time do much to keep the air of the stable pure and wholesome. All must have noticed the strong smell of ammonia in close horse stables. This can be prevented by the free use of chemical absorbents. Among the most useful of such materials are land-plaster, kainit, acid phosphate, superphosphate plaster, and sulfate of magnesia.

All of these materials help to prevent the escape of ammonia into the air for the reason that the ammonia enters into combination with the acids of the substances used, and thus forms a salt of ammonia which is not volatile. Land-plaster may be freely used beneath and behind the animals without danger. The other materials, all of which are more active chemically in preventing the loss in question than plaster, should be used in the stable in more moderate quantities; and the use of the kainit and sulfate of magnesia, at least, should be confined to the gutters. They should not be thrown where the animal must stand in them, as they are likely to cause sore feet, especially in the case of cattle, if carelessly or too freely used. The quantity of either of these materials required usually varies between about a pound and a pound and a half per animal, daily. In European experience, superphosphate plaster has been found one of the most satisfactory absorbents for the prevention of loss of ammonia. Kainit is also very effective. This material, besides serving to prevent loss of ammonia, enriches the manure in one of the most important constituents of plant-food, potash, which it should be remembered is precisely as useful when the kainit is first used in the stable and goes to the field mixed with the manure as it would be if it were directly applied to the soil. Indeed, it is likely to prove more useful because, being first mixed with the manure, it is likely to be very evenly distributed. Any of the materials named may be freely scattered in manure pits, or cellars, or wherever manure is stored, with distinct advantage.

The rotting or fermenting of manure.

The rotting of all classes of farm manures is a consequence of exposure to the air and the action of bacteria or other minute vegetable organisms whose growth in the manure causes fermentation. The rotting of manure is affected both as regards the rate at which it takes place and the nature and the results of the fermentations which go on in it by varying conditions. Most important among these are:

(1) The temperature.—The higher the temperature the more rapid the fermentation and the greater the danger of loss of valuable constituents.

(2) By the degree of compactness of the heap.—Fermentation goes on more rapidiy in proportion as the mass is light and open so that the air gains free access to all parts of it. Fermentation takes place more slowly and the temperatures are lower in proportion as the manure is compact.

(3) The degree of moisture.—Water in manure, as in soils, tends to lower the temperature and thus to retard or prevent fermentation. It also in part excludes the air. The rate of fermentation, therefore, can be controlled to a considerable extent by the free use of water. If a heap of manure is found to be excessively hot, the addition of water, especially if accompanied by trampling, will check the too rapid fermentation.

(4) By the composition of the manure.—The rate at which fermentation will take place in manure depends under otherwise similar conditions very largely on the percentage of soluble nitrogenous matter it contains (urea, hippuric acid, etc.). The greater the proportion of soluble nitrogen-containing compounds, the more rapid the fermentation. This more rapid fermentation in the case of manures containing abundant soluble nitrogenous matter is chiefly due to the fact that such material serves as food for the micro-organisms causing fermentation. The soluble nitrogen

compounds named are found chiefly in urine, hence it follows that, when the urine is all saved and carefully mixed with the manure, fermentation goes on more rapidly than under other conditions.

The effects of decomposition.

As manure rots, one of the first changes noticed is the increase in its temperature. If a mass of manure is relatively loose and if it contains a considerable amount of moisture and soluble nitrogen-containing compounds, its temperature rises rapidly. As a result of the heating of the manure, a part of its water is evaporated; the manure becomes more and more dry, and in extreme cases, as in loose piles or heaps, manure may finally become almost perfectly dry. It turns white and is said to be "fire-fanged." When manure reaches this condition, it has usually lost a considerable proportion of its valuable constituents, the most important being nitrogen. Another prominent result is the decrease in the proportion of organic matter, which, practically speaking, is burned. As a result of this destruction of organic matter, a large amount of carbon dioxid passes into the air, and the capacity of the manure to furnish humus to the soil is decreased. At the same time that these changes are going on, ammonia and carbonate of ammonia may be formed, and as both of these compounds are volatile, they may, to a considerable extent, pass into the air. Such are some of the first results of decomposition under unfavorable conditions. Meanwhile, the bacteria connected with fermentation have been at work.

The bacteria found in manures may be divided into two classes: first, bacteria requiring free oxygen (aërobies); and second, bacteria which thrive in the absence of free oxygen (anaërobies). The aërobies are found in those parts of the mass of manure to which the air has access. Here we find bacteria which feed on soluble nitrogen-containing compounds and take oxygen from the air. As a result of the activity of bacteria of this kind, nitric acid is formed. If the manure is exposed to water, much of this nitric acid will be dissolved in the rain-water and carried into the lower and more compact parts of the pile. Here are found the anaërobies. Bacteria of this class feed largely on the carbon-containing parts of the manure derived in considerable measure from straw and similar materials used for bedding. These bacteria seize on the nitric acid for the combined oxygen it contains. In a certain sense of the word, these bacteria breathe nitric acid, but in so doing, they destroy it. They separate the oxygen from the nitrogen and the latter escapes into the air in the free form. Bacteria of this class are nitrate-destroyers.

Manure is usually rotted out of doors in piles known as compost heaps. (Fig. 667.) In these heaps, leaves and garden refuse are often incorporated. The composting of manure is a favorite practice with gardeners. Sometimes lime is added to hasten decomposition. In the South animal manures and cotton seed are often thoroughly mixed with acid phosphate rock and kainit, and all thrown into a heap to undergo fermentation. The acid phosphate supplies the deficiency of phosphorus in horse manures, while the sulfate of lime that it contains prevents the loss of ammonia during fermentation.

Summing up the facts which have been stated, we see, then, that under unfavorable conditions, rotting manure may lose water and become "fire-fanged." It loses organic matter, so that it carries less humus to the soil; it may lose ammonia; and it may lose nitrogen in the free form. In an experiment conducted by one of the Experiment Stations in New York, it was found that a pile of cow manure in the open air, which when fresh weighed 2,399 pounds, in the course of a year lost 1,150 pounds in weight and decreased one-half in bulk. Chemical analysis showed that it had lost 46.6 per cent of its manurial constituents. The change of the original nitrogen-containing compounds of the fresh excreta into ammonia and nitrates is favorable to the prompt action of the manure. These changes will take place in the soil if the manure is applied in the fresh or unrotted condition, but this is not always possible and the question therefore becomes important. It is for the farmer to determine how manure can be managed so as to promote the favorable changes and to prevent the losses.

Farm manures compared with fertilizers.

It is not uncommon to see farm manures compared with fertilizers on the basis of their respective content of nitrogen, phosphoric acid and potash. Such comparison is not believed to be a correct basis for determining relative value, since manure serves certain purposes that fertilizers cannot serve. Farm manures are of very complex composition. They contain more or less of all the

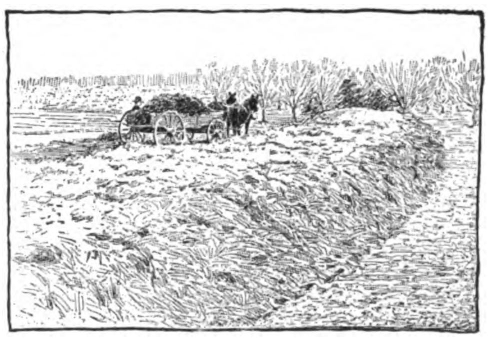


Fig. 667. Stacking yard manure that contains much bedding.

elements contained in the food given to the animals and in the litter. They are rich in organic matter, being composed chiefly of vegetable substances. This organic matter is a source of humus to the soil and may be of much value.

Those elements of plant-food that we find in manures and which are not ordinarily deficient in soils, as lime, magnesia and sulfur, are not without their value; yet it has been customary to value manures on the basis of the nitrogen, phosphoric acid and potash they contain. True, their value is determined chiefly by the proportions of these elements, but the secondary elements are also of value. Soils, moreover, need humus. Manure supplies this. Fertilizers do not, and when the effort is made to keep land in good productive condition without the use of manures, it is commonly essential to adopt special measures for the production of humus, as by the occasional introduction of green-manuring crops, or occasionally putting the land into mowing for a series of years. It is true the plant-food elements in fertilizers are often somewhat more promptly available than in manures; but while this in itself is an advantage, it is also a danger, for the chances of loss are thereby increased. With skilful use the probability of loss of plant-food elements applied in fertilizers is greatly reduced, and there is considerable experimental evidence to show that a given quantity of nitrogen in the form of some of the best nitrogen fertilizers, such as nitrate of soda, will increase crops to a greater degree than the same quantity of nitrogen in manures. Nevertheless, the latter appear to give to arable soils certain qualities which can scarcely be secured except by their use, and it will be generally conceded by those qualified to judge that farm manures are sometimes worth more to the farmer and gardener than the figure obtained by estimating at usual trade values the nitrogen, phosphoric acid and potash they contain.

Composition of barnyard or cattle manure.

This term as here used designates the manure made on the farm chiefly from cattle. Throughout the northeastern part of the country this manure is mostly from milch cows. Manure of this character contains considerably more water than the manure of either horses or sheep. Its average plant-food content is lower than well-kept manure from either of these animals. Barnyard manure being relatively wet and poor in soluble nitrogen compounds, ferments and heats slowly. It ranks as a cold manure. In composition it varies very widely. The results of 79 analyses made in the Experiment Station at Amherst, Massachusetts, showed a range as follows: for nitrogen, 1.36 to 0.21 per cent; for phosphoric acid, .75 to .10 per cent; for potash, 1.40 to .13 per cent. Snyder reports the range for the same elements to be for nitrogen, .8 to .4; for phosphoric acid, .9 to .3; for potash, .9 to .3. The averages of the analyses made at Amherst and those reported by Snyder are as follows:

	Water	Nitrogen	Phosphoric acid	Potash
Amherst average .	65.9	0.454	.333	0.561
Snyder average. .	. .	0.50	.35	0.50

The average of twelve well-made samples of manure (mostly from milch cows), on which hogs were kept as it accumulated, was as follows: water, 65.9 per cent; nitrogen, 0.454 per cent; phosphoric acid, 0.33 per cent; potash, 0.56 per cent. The higher figure for potash in the later averages is without doubt due to the fact that the potash in these samples of manure had been perfectly conserved, as there was no possibility of waste of urine or drainage from the manure.

For practical purposes, one will be sufficiently accurate in estimating well-kept barnyard manure to contain one-half of one per cent each of nitrogen and potash and one-third of one per cent of phosphoric acid. On this basis, a ton of manure would contain ten pounds each of nitrogen and potash, and six and two-third pounds of phosphoric acid. A cord of well-preserved manure kept without loss of urine and without exposure to the weather will weigh a little more than three tons. A cord of such manure, therefore, should contain about thirty pounds of nitrogen and potash and twenty pounds of phosphoric acid.

Composition of stable or horse manure.

The manure from horses, in this country commonly known as stable manure, is generally more valuable than that from the other larger domestic animals excepting sheep, provided it has been well kept. It is richer in nitrogen and usually also in phosphoric acid and potash than the manure of either cattle or hogs. It contains relatively little water and ferments rapidly. During fermentation it usually attains a high temperature, and unless kept very compact and moist, it is likely to become fire-fanged. This quality of quick fermentation and heating makes it the most valuable manure for hotbeds as well as for cold, wet soils and for use in truck-farming, where early maturing crops are an especial object. As usually obtained from city and town stables, its composition and value vary greatly because of the variation in the quantity of litter used and the way in which the manure has been saved and handled. This manure averages much lighter in weight than the manure from cattle, usually ranging between about one and one-half and two tons per cord.

Experiments at the Cornell Experiment Station, showed horse manure to have the following composition: water, 48.69 per cent; nitrogen, 0.49 per cent; phosphoric acid, 0.26 per cent; potash, 0.48 per cent. Plaster was very freely used in this experiment and this doubtless reduced the percentages, so that the figures are undoubtedly below the average.

Composition of sheep manure.

Sheep manure is generally accumulated under the animals with sufficient litter to keep the latter dry and clean. Under these conditions, there is commonly no appreciable loss either of urine or of ammonia because of excessive fermentation. The amount of urine voided by sheep is relatively small and the elements of value in sheep manure ordinarily suffer less loss than is common in the case of other kinds of farm manure. When sheep manure is finally removed from the pens and put into loose piles, as is often the case, in order that it may be worked into suitable mechanical condition to spread, it very rapidly undergoes decomposition and heats quickly. It is then likely to lose a part of its nitrogen in the form of ammonia. To prevent this it is well to scatter kainit or land-plaster as the pile is built up. The average of four analyses of sheep manure made at the Massachusetts Experiment Station showed it to contain: water, .2922 per cent; nitrogen, 1.44 per cent; phosphoric acid, .92 per cent; potash, 1.17 per cent. Sheep manure is now sometimes collected, dried and ground, and put on the market as sheep guano. In this form it is a concentrated manure, especially valuable for dressing lawns, for use in hothouses, and like purposes.

Hog manure.

The manure made from swine undoubtedly varies more widely than that from the other domestic animals, because of the wider variations in the nature of their food and the conditions under which they are kept. The excrements of swine on most farms are not kept by themselves but are mixed with other manures, and this in general would seem to be the better system of management. Hog manure, if kept by itself, is relatively watery and is usually poor in nitrogen and rich in phosphoric acid. It decomposes slowly and must be ranked as a cold manure.

The quantity of manure that can be made on the farm.

The experienced farmer will know from the results of earlier years about the quantity of manure that will be made from a given number of animals. For a beginner, some rule whereby the amount to be made can be estimated with reasonable accuracy will be useful. As the result of careful experiments, German investigators give the following rules to determine the quantity of manure that will be made: Multiply the dry matter in the food consumed by the different classes of

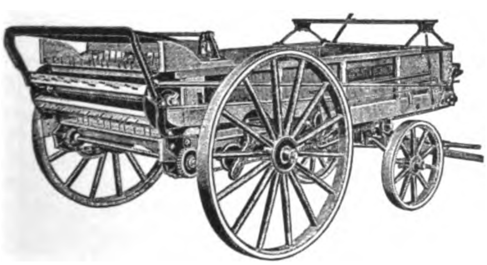


Fig. 668. A manure spreader.

farm animals by the following factors: for the horse, by 2.1; for the cow, by 3.8; for the sheep, by 1.8. To the product in any case, add the weight of the bedding used. The horse of average size consumes daily about 24 pounds of dry matter and makes, therefore, 2.1 times 24 pounds, or 50 pounds of manure daily. The cow of average size consumes daily about 25 pounds of dry matter and makes 3.8 times 25 pounds, or 95 pounds of manure daily. A 125-pound sheep consumes about 3 pounds of

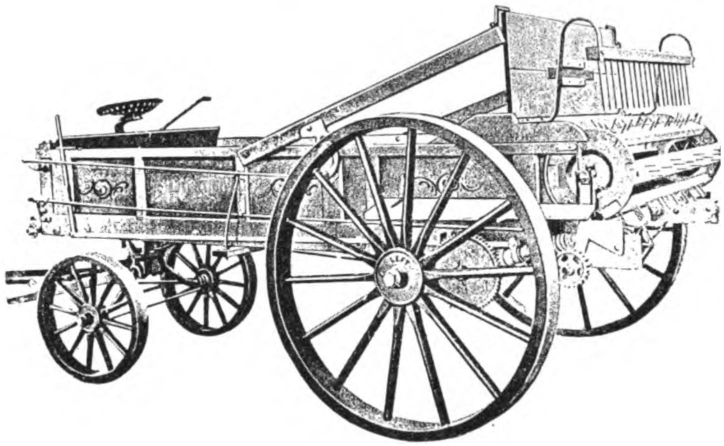


Fig. 669. Left and rear view of a spreader, with safety board raised in position for spreading.

dry matter daily and makes 1.8 times 3 pounds, or 5.4 pounds of manure daily.

If, for any reason, not all the excreta are saved, as is the case when horses are at work or cows at pasture part of the time, suitable reduction in the amount must be made. The applicability of these figures to the conditions prevailing on American farms has not been thoroughly tested. The few experiments which have been made indicate a rather lower rate of production.

The application of farmyard manures.

Whether manure should be rotted before application or applied fresh must be determined by conditions. For quick-growing crops, partially rotted manures are generally preferred. In ordinary farming, for most crops, the application of fresh manure should, in general, be the rule. It is believed that in the majority of instances thorough incorporation of the manure with the surface soil by use of the disc harrow will give the best results, and such incorporation with the soil would best promptly follow spreading. Experience indicates that there can be no considerable loss from manure spread on level land if left on the surface. Still, when conditions permit, incorporation with the soil is safer. Manure is not infrequently spread during the winter, when, perforce, it must remain on the surface until the following spring. Experiments indicate that if the land is sufficiently level, so that there will be little surface wash, this method of application is to be preferred to the double handling which, in many cases, would be the alternative. The relative leisure of the winter months constitutes a strong argument in favor of this practice with many.

In ordinary farming, the quantity of manure applied per acre usually ranges between 4 and 8 cords. Among market-gardeners far larger applications are common. Such gardeners occasionally make applications at the enormous rate of 30 to 40 cords per acre. The high value of their lands and the consequent necessity of stimulating them to the utmost possible production, justify such practice.

The manure-spreader has now reached a degree of perfection such that its use can be strongly recommended, especially to those applying coarse manures, and desiring to put them on in the best possible mechanical condition in order that the benefit derived from them may be as great as possible. (Figs. 668, 669.)

Poultry manures.

Poultry manures are richer than the other farm manures when well preserved. There are two principal reasons for this: First, the food is richer, as a rule; and second, the excretion corresponding to the urine of the larger domestic animals is semi-solid, voided with the dung, and not subject to direct loss. Poultry manures as a rule are rich in nitrogen and phosphoric acid, because the foods given the fowls are rich in these elements. These manures are relatively poor in potash, although they may contain a larger percentage of this element than do the other farm manures. The composition is subject to wide variation. The table below shows the results of analyses:

Literature.

The subject of farm manures is discussed at greater or less length in many books on agriculture, and in bulletins and other publications. The literature is very varied. The following are some of the more important references: Griffiths, Farm Manures; Aikman, Manures; Brooks, Manures, Fertilizers and Farm Crops; Roberts, The Fertility of the Land; Storer, Agriculture; Wolff, Düngerlehrer; Harris, Talks on Manures; Sempers, Manures; Barnyard Manure, Analyses, Connecticut State Report for 1889 (Compilation); Barnyard Manure, Analyses, Hatch Experiment Station Report for 1897 (Compilation); Barnyard Manure, Availability of Nitrogen, New Jersey Experiment Station Reports for 1899, 1900, 1901, 1902, 1903; Barnyard Manure, Denitrification, New Jersey Experiment Station Report for 1900; Losses in Barnyard Manure, New Jersey Experiment Station Bulletin No. 150; Pennsylvania Experiment Station Bulletin No. 63; New York, Cornell Bulletin No. 13; Preservation of Barnyard Manure, Massachusetts Experiment Station Bulletin No. 81; Cornell Bulletin No. 27; Ohio Experiment Station Bulletin No. 134; North Carolina Experiment Station Bulletin No. 61; Manure Production, Alabama Experiment Station Bulletin No. 114; Production of Manure, New York, Cornell, Bulletin No. 56; Manure Production by Horses, Pennsylvania Experiment Station Report for 1892.

COMPOSITION OF POULTRY MANURES

	Water	Nitrogen	Phosphoric acid	Potash
	Per cent	Per cent	Per cent	Per cent
Hen manure, fresh, according to Storer	56.00	1.60	1.50–2.00	0.80–0.90
Hen manure, fresh, analysis by Goessmann	52.35	0.99	0.74	0.25
Hen manure, dry, average two analyses, Goessmann	8.35	2.13	2.02	0.994
Duck manure, fresh, according to Storer	56.60	1.00	1.40	0.62
Goose manure, fresh, according to Storer	77.10	0.55	0.54	0.95
Pigeon manure, according to Storer	52.00	1.75	1.75–2.00	1.0 –1.25

Poultry manure ferments very quickly and, as frequently handled, loses much of its nitrogen in the form of compounds of ammonia, which are rapidly formed and which escape into the air unless means to prevent are taken. The mixture of poultry manures with such materials as land-plaster, kainit, acid phosphate or superphosphate plaster is almost imperative for satisfactory preservation. Often dry earth or powdered dry muck are also excellent materials to mix with it. If kainit alone is used, poultry manure remains very moist and will be found difficult of application. Director Woods, of the Maine Experiment Station, recommends mixing the manure with a moderate amount of dry sawdust, which helps to preserve it in good mechanical condition. As a result of experiments carried out in the Massachusetts Experiment Station, it is concluded that the annual excreta that can be collected beneath the roosts per adult barnyard fowl will amount to about 30 to 45 pounds, according to the breed.

FARM PRACTICE WITH STABLE MANURES

By *I. P. Roberts*

In the generic sense, manure is any substance applied to the soil for the purpose of maintaining or increasing productivity. It may do this in the following ways: (1) by furnishing additional plant-food; (2) by improving the physical conditions of the soil; (3) by producing such chemical or biological action in the soil as will assist in liberating plant-food; (4) (in rare cases) by seeding the soil with nitrifying organisms. Manures intelligently applied may produce many, sometimes all, of these beneficial effects.

Manures classified.

The solid and liquid voidings of animals are spoken of as excrements; when mixed with straw or other absorbents, they are spoken of as manure or barn manure. Commercial manures, "fertilizers," are more or less concentrated forms of nitrogen, phosphoric acid and potash, mixed or unmixed. Green-manures are living plants designed to be plowed under to improve the texture of the soil, to furnish humus, and to increase available plant-food. One of the most economical and satisfactory methods of changing unavailable into available plant-food in the soil and the manures applied, is to make a more extended use of green-manure crops, which usually may be grown between the gathering of one crop and the planting of another. Amendments, such as lime, are substances which, when applied to the soil, may correct too great acidity, improve friability, and hasten beneficial chemical and biological action, and in some cases supply mineral constituents of plants.

Rate of production of manure.

Extended investigations at the Cornell Experiment Station showed that the following amounts of excrements were produced daily for each 1,000 pounds of live weight of animal:

	Pounds
Sheep	34.1
Calves	67.8
Pigs	83.6
Cows	74.1
Horses	48.8
Fowls	39.8
Total excrements	348.2
Total manure	388.0

If straw bedding be added, which is nearly or quite equal to excrements in potential manurial value, it will be seen how large a quantity of manure is produced from 6,000 pounds of mixed live-stock. A dairy of twenty 1,000-pound cows comfortably fed, would produce, in the six winter months, 133⅓ tons of excrement, or 146⅓ tons of manure. Animals fed a highly nitrogenous ration, say 1:4 (as were the pigs in the above investigation), consume large quantities of water and hence produce large quantities of excrements, especially liquid, the weight of which usually exceeds the weight of food consumed; while those fed on a wide ration, say 1:9, consume comparatively little water and hence produce less weight of excrements.

Factors that determine the use of manures.

Barn manures are most economically efficient in general farming when applied in moderate quantities and in conjunction with superior tillage. Light applications of caustic lime, even as little as five bushels per acre, often produce marked beneficial results on manured land. If the plant-food in manures, liberated by decay, is not quickly used by living plants, some of it will be lost and much will become less available, or "lazy"; hence, manures should be applied where plants are already growing, or incorporated with recently prepared ground where plants will soon be growing.

A thousand pounds of wheat, 16⅔ bushels, and 2,000 pounds of straw (an average crop per acre) require 27 pounds of nitrogen, 12.4 pounds of phosphoric acid, 17.9 pounds of potash. Ten tons of fresh unrotted manure from horses and cattle fed a moderate grain ration contain 136 pounds of nitrogen, 44 pounds of phosphoric acid, 120 pounds of potash. In farm practice it is estimated that the first crop grown after manuring may utilize, under favorable conditions, one-half of the plant-food contained in the manure applied. The plant-food available in ten tons of good fresh manure is, nitrogen 68 pounds, phosphoric acid 22 pounds, potash 60 pounds. Thirty bushels of wheat and 2,600 pounds of straw require, approximately, 46 pounds of nitrogen, 21 pounds of phosphoric acid and 27 pounds of potash.

The average of 34 soils analyzed by various American chemists showed that in the first eight inches of soil an acre contained potential plant-food as follows: nitrogen 3,217 pounds, phosphoric acid 3,936 pounds, and potash 17,597 pounds, making a total of 24,750 pounds, or more than twelve tons. These figures make it evident that it is not fertility that is wanted, but productivity. Since even a moderate dressing of manures almost invariably increases productivity, it follows that tillage is

Fig. 670. Tillage needed more than manures or fertilizers Middle plot was both fall- and spring-plowed.

deficient or that the plant-food in the soil is largely unavailable, that is, woefully lazy; or that the soil is not continuously moist enough for normal growth of plants, or that it is too moist; or that the climate is not well suited to the crops grown; or that the seeds lack potency. It is evident that the subject of productivity as affected by manures should always be considered in conjunction with the other factors which may assist or materially retard the potential power of manures. It is also evident that it is not good economy to raise maximum crops by the excessive application of manures and ignore the physical condition of the soil or the potency of the seeds and grains sown or the plants set.

Factors affecting the value and quantity of animal excrements.

Certain conditions affect the value and quantity of animal excrements. It is found that the excrements produced by animals are equal in value to 30 to 60 per cent of the cost of their food if the plant-food they contain is computed at the price of the same constituents in commercial fertilizers. Young animals produce poorer excrements than mature ones. The excrements of those animals that make a product, as milk or young, are poorer than those from non-productive animals. The more abundant the ration, the greater the value of the excrements. Nitrogenous and concentrated foods result in more valuable excrements than unconcentrated and carbonaceous foods. Liberal salting and succulent food tend to increase quantity and diminish value per unit of excrements. The amount and kind of bedding may affect the value per unit of manures. Animals in a cold environment drink little water, digest their food closely, and produce excrements relatively small in amount and poor in quality. High-grade and well-rotted manures are relatively more valuable per unit of contained plant-food than poor and unrotted manures, as they contain relatively more quickly available plant-food. Hence, coarse low-grade manures should be rotted to improve their availability, since plants are most benefited when they receive abundant nourishment in the early stages of their growth. High-grade fertilizers and high-grade manures are worth more per unit of their most valuable constituents than are those of low grade.

The value of manure as set down below is determined by investigation during the winter months, and the nitrogen, phosphoric acid and potash are computed at 15, 6 and 4½ cents per pound, respectively. The indirect benefits of manures may be considered an equal offset for the slightly less availability of their plant-food constituents as compared with fertilizers:

Kind of manure	Value per ton
Sheep	$2 30
Calves	2 17
Pigs	2 29
Cows	2 02
Horses	2 21

Limited amounts of bedding were used in the tests from which the above figures were made. The plant-food in straw is not so quickly available as it is in the excrement of animals.

The following table exhibits the value of manure from different animals of average or aggregate weight of 1,000 pounds:

Kind of animals	Value per year
Fowls	$51 10
Sheep	26 09
Calves	24 45
Pigs	60 88
Cows	29 27
Horses	27 74

Manurial value of a ton of the usual bedding material computed as above:

	Nitrogen	Phosphoric acid	Potash	Total
Barley straw	$1 65	$0 34	$1 74	$3 73
Oats	1 38	33	1 59	3 30
Rye	1 47	30	77	2 54
Wheat	1 44	26	57	2 27

Usually animals on the farm are housed only for six to seven months of the year, and however well the manures are cared for, inevitably some loss will occur; therefore, the values as given above should be reduced more than half. In many cases, less than one-fourth of these values is secured, and in some cases no value whatever is realized. The waste of the valuable constituents of manures in the United States is still very great, exceeding in value, it is thought, the amount of taxes paid on land devoted to agriculture. However, the value of manure is better realized than formerly and more rational methods are now practiced by progressive farmers in the care and application of barn manures.

Care of manures.

In some cases manures are stored in covered yards or pits; in others, they are distributed over the fields as fast as they accumulate; in either case waste is largely avoided. If stored for a time, care is taken to prevent fire-fanging by the use of water, or leaching by the use of absorbents, such as straw, dry muck, and salt and gypsum, both of which tend to prevent waste of the soluble plant-food which the manures contain. Gypsum is especially beneficial when used in the stable or mixed with the manure when stored until it is convenient to distribute it on the field.

If the manures are scattered over large open barnyards, or are left under the eaves of the stable for considerable periods of time, no realization of their quantity and value is secured. In the northern and central parts of the United States, the average rainfall exceeds thirty inches per annum. Many barnyards which serve, among other things, for the storage of manures for at least half of the year, contain an eighth to half an acre of land. One inch of rainfall equals 113 tons of water per acre. If this be multiplied by 15, one-half the inches of annual precipitation, we are able to get some conception of the loss of manures baptized at the rate of seventeen hundred tons of water per acre during six months, approximately the time manures are often exposed in barnyards. Account must also be taken of the fact that the most available, and hence the most valuable constituents are lost by weathering. Manures exposed at Ithaca in loose heaps of two to ten tons for six months showed loss of values as follows:

	Per cent
1889 horse manure	42
1890 horse manure	62
1890 cow manure	30
1889 mixed manure (compacted)	9

In other cases, when small quantities of gypsum were mixed with the manure, the losses were notably diminished.

Importance of tillage as related to manuring.

No matter how carefully the manures are handled and applied, or how intelligently green-manure crops are used, full results cannot be secured unless superior tillage is practiced. The facts previously stated show that many, if not most arable soils contain vast quantities of potential plant-food, and that the yield of crops raised on them indicates that but a very small fraction of this plant-food is available for the production of any single crop. Jethro Tull and recently others have proved that tillage may be made the great factor in increasing productivity; and it has also been proved that it is not economical to neglect tillage and seek to produce maximum crops by the application of large quantities of manures or fertilizers. The soil should be made to furnish the larger part of the nourishment required. Manures and fertilizers are most intelligently used as "starters," that is, to furnish acceptable, quickly available nourishment for the young plants.

Applying manures.

Manures, and even fertilizers, should be distributed evenly and thinly, and, when convenient, immediately mixed with the surface soil. However, in some lines of horticulture and floriculture, manures may be applied lavishly to advantage. Sometimes the chief object of their use is to secure moist heat, as in hotbeds made of raw or unrotted horse manure; while the colder, more watery cow manure, mixed with soil, is used for forming a rich acceptable potting earth. Weathered solid cattle voidings, or cow chips, when mixed with rich earth, preferably rotted sods, furnish ideal potting earth. Horticulturists and nurserymen frequently keep dairy or other cattle that they may have an abundant supply of unleached, bovine manure, which is so valuable in these specialized branches of agriculture. Commercial manures are used only in small quantities, in floriculture, either directly or in solution, and usually only for some specific purpose.

THE USE OF GREEN-MANURES IN SOIL-IMPROVEMENT

By *E. B. Voorhees*

The fertility of soils may be improved in two directions by the use of natural methods: first, by keeping the soil continually occupied by a growing crop and thus saving in the soil for the use of the plants those constituents which by improvident and irrational methods of practice are likely to be lost; and second, by adding to the soil vegetable matter which improves its absorptive power, increases the activity of the constituents already there, besides introducing the element nitrogen. The various crops that may be used to attain these purposes do not possess equal value, and unless the principles which govern their use and the conditions under which they are grown, as well as the influence of the crops on future productivity, are well known, the results may not always be satisfactory.

Two groups of plants.

In the first place, the crops that may be used are divided into two distinct groups. In one group are included those plants which can secure the necessary nitrogen for their growth only from soil sources, called "nitrogen-consumers," and therefore, when plowed under do not add to the soil any essential constituent element, and are only serviceable in preventing losses of soluble constituents and in improving the physical character and absorptive properties of soils. The members of this group include the cereal grains, the grasses, buckwheat, turnips, rape, and like crops. Because of their time of growth and period of rapid development, it is often desirable to grow them, particularly when the primary purpose is to prevent losses of plant-food rather than rapidly to build up the soil in nitrogenous organic substances.

The second group of crops includes those plants which belong to the legume or clover family, and which do not depend solely on soil sources for their nitrogen, but can secure it from the air; these in their growth and removal from the soil may not materially reduce the content of soil nitrogen, but rather add to the crop-producing capacity of soils by improving their physical character and by increasing their store of nitrogen. In order that a plant of this group may secure its nitrogen from the air, however, the soil must contain originally, or be inoculated with a specific organism, the presence of which in the soil is manifested by the growth of nodules on the roots, and through which it is believed the plants secure their nitrogen, though the exact process is not yet fully understood. Plants of this group are clover of all kinds, sweet clover or melilotus, vetch, alfalfa or lucerne, peas, beans, cowpea, the so-called Japan clover (lespedeza), beggar-weed, soy bean, lupine, sainfoin, serradella, lentil, peanut, and very many herbs and trees.

The advantages of legumes as green-manures.

The use of this class of plants, therefore, possesses a threefold value in the improvement of soils: first, in absorbing and retaining the soluble food in the soil; second, in providing vegetable matter, or humus-forming material, which contributes to the physical improvement of the soil, and third, in adding to the store of nitrogen the element most likely to be deficient, and which can be used by plants whose sole source of nitrogen is the soil. Fortunately, because of the number of plants belonging to this last group, and because of their wide range of adaptation to various conditions, it is possible to introduce one or more of them into the regular system of farm practice without interfering with useful and profitable rotations. Many of them, for example, the various clovers, as red, crimson and alsike, are already grown extensively, and their value in the rotation is well understood by practical men. There are many others, however, whose characteristics have not been carefully studied until recent years, and whose usefulness is just beginning to be appreciated. Among these are the Canada field-pea, the soy bean, the cowpea and the various varieties of vetch, all possessing that valuable power of appropriating for their use the free nitrogen of the air. The plants of this group are often called, and properly, "nitrogen-gathering" crops, and their renovating and improving character is seldom overestimated. A brief discussion of the various plants suitable as renovating and improving crops, together with their characteristics and relative advantages, and their uses, may now be made.

"Nitrogen-consuming" catch-crops.

A crop very generally used, particularly in the East, is rye, primarily to prevent losses during late fall and winter. The advantages of this crop are that it may be seeded late in the year, after other crops have been harvested, grows rapidly, withstands the winter well, is a good forager and makes a rapid, early growth which may be plowed down for early crops, as corn, potatoes, tomatoes, and the like. Furthermore, the cost of seeding is small, and farmers are familiar with the handling of the crop. Its chief value, however, lies in its hardiness, withstanding well severe weather, and its habit of late fall and early spring growth, which holds the soil and prevents washing and mechanical losses; it readily absorbs the available food in the surface soil, and even when plowed down early contributes in some degree to the humus-forming substances in the soil, and thus improves the absorptive properties.

Wheat possesses the characteristics that have been mentioned for rye, though not in the same degree. The seed usually costs more, and satisfactory growth requires a better preparation and fertilization of soil; besides, the plant is not so hardy and starts later in the spring. It is, therefore, as a rule, less satisfactory for the purpose than rye.

Buckwheat is another plant of this group that has been used very largely as a soil-improver, particularly in the breaking up of new lands, and for this purpose is a useful crop. Its season of growth is during the summer months of July and August, when conditions are usually favorable for the progress of those activities which cause changes in the soil substances, and hence, it is able to make a relatively large growth on medium poor land; when grown as a renovating crop it improves the physical character of soils by keeping them covered during the hot season and by adding vegetable matter.

Certain varieties of mustard are extensively used as a summer catch- or fallow-crop in other countries, particularly Germany. The plant grows rapidly and is able to subsist on rather poor soils, thus accumulating in the surface soil materials more readily appropriated by other plants. However, it does not present any advantages for American conditions not possessed by the more familiar crops grown here.

The turnip possesses characteristics of value, owing to its rapid appropriation of food in cool weather, and consequent large accumulation of organic matter in late fall. Those varieties that root deeply are preferable, because they gather a part of their food from lower layers of soil and store it in their enlarged bulbous roots near the surface; besides, this peculiarity of growth is an important factor because it exerts a favorable influence on the physical character of the soil. It causes a separation of the soil particles, and permits a freer access of air. To secure the full benefit of this crop as a green-manure, it should be plowed down in the late fall.

Dwarf Essex rape may be grown as a cover in the late fall and to serve as a mulch during the winter, and, for these purposes, serves admirably.

All of the crops here mentioned may be made virtually catch-crops, thus not interfering with a regular rotation. Even if pastured or completely removed, they leave the soil in better condition than if no crop had been grown. The soil is improved because its functions have been exercised; and at a minimum of expense.

"Nitrogen-gathering" catch-crops.

Of the "nitrogen-gatherers," the clovers, as a class, are perhaps the best known, though a brief description of the characteristics of the various useful plants belonging to this group will be helpful.

Red clover.—The renovating character of a crop of red clover is well known, and even when only stubble and roots are the source of the additions made to the soil, the improvement that follows is very marked. Farmers know that corn or wheat seeded on a clover sod will do much better than when seeded on raw ground or on sod from grasses. The ameliorating influence of this crop on soils is due primarily to two causes: first, to the extensive root system, which is distributed widely throughout the soil and to great depths in it, thus changing, to some extent, physical character as well as storing food in a large tap-root near the surface of the soil, in readily decaying organic forms; second, because the plant is a nitrogen-gatherer the crops of clover removed do not exhaust the soil of nitrogen, but rather add to its store, and hence the succeeding crops have at their disposal a larger amount of this element than if they were preceded by the grasses or cereals, which are "nitrogen-consumers." The wider and more frequent use of red clover can be commended from all standpoints when the increase and maintenance of natural fertility are important. Red clover should be seeded at the rate of 15 pounds per acre, preferably sown broadcast, and lightly covered with a harrow or weeder, and, on light soils, rolled after covering.

Mammoth clover is a near relative of the red and resembles it closely. It is a coarser plant and a greater forager. When clover is grown solely for use as a green-manure, the mammoth may often be substituted with advantage for the red. It is also better adapted to wet lands than the red. It is seeded at the same rate.

Alsike clover.—Alsike clover has a semi-creeping habit, and does well only when seeded with a kind making a more upright growth, as the red or mammoth. The mixture is desirable, since the alsike is better adapted to cold, moist soils and is hardier than the others, withstanding winters that kill the red and mammoth varieties. The seeding may be made with advantage during the summer and early fall, without nurse-crop, either for turning under in spring as green-manure or for hay or pasture.

Such seeding should be made on soil well-prepared, and the seed lightly covered. Since it is better to sow alsike clover with red clover, a mixture of 5 pounds of red and 5 pounds of alsike are sufficient to provide a good stand. Alsike clover seed is about half as large as red clover seed.

Crimson clover.—Crimson clover is an annual, and because of its useful characteristics has made a place for itself in American agricultural practice. Its habits of growth are not so well known as those of the other kinds described, and for this reason, among others, it is not so generally distributed even in those sections where it thrives well. Its habits are such as to make it undesirable to substitute for the red, though it may well supplement it, and thus add another useful cover crop to our list. It is essetially a cool-weather plant, thriving well in late fall and early spring, and maturing seed in the middle states about June 1. These characteristics of growth make it especially suitable for a green-manure catch-crop which may be used without interfering with regular rotations. It has proved hardy in the eastern and middle states, though many failures are reported, which are probably due in large part to the failure to observe in its seeding the peculiar habits and characteristics of the plant. The impression that because it is a catch-crop it will grow well on poor soils with other crops, under all conditions of season and climate and without particular care in seeding, is erroneous. Like other plants, crimson clover must have food—it is affected by drought and cold and severe weather; it cannot subsist with other crops which rob it of moisture and plant-food, and it must be carefully seeded in order to insure against adverse conditions, though when conditions are favorable it will catch and grow from a simple sowing of the seed on raw ground.

Crimson clover should preferably be seeded at the rate of twelve to fifteen pounds per acre, on a well-prepared seed-bed, and lightly covered with a harrow or weeder. It is not suited to spring seeding, as it ceases to grow as soon as hot weather comes; the best period for seeding ranges in the eastern and middle states from July 15 to September 1. It may therefore be used as a catch-crop, seeded in corn, berry patches, orchards and the like, after the regular cultivation has ceased for the season, and after early potatoes, tomatoes and other crops harvested early enough in the season to enable it to get a root-hold and to make considerable top before cold weather sets in. While it requires a good soil for its best development, it is well adapted to light, sandy soils that are well suppiied with mineral food. It will grow later in the fall than red clover because not injured by light frosts, and also makes a more rapid spring growth than any of the other clovers seeded in the late summer.

When the land is light and poor, a dressing of acid phosphate, say at the rate of 150 pounds per acre, will materially aid in securing a catch and insuring a crop of crimson clover. Its early maturity is one of its most valuable characteristics from the standpoint of its use as a green-manure, making it possible when seeded in corn, for example, to secure a considerable crop in time to plow down for another corn crop. When the plants are largely destroyed because of severe winters, the accumulated nitrogen and organic matter in the fall is sufficient to repay amply the cost of seed and seeding. Studies made at the New Jersey Experiment Station show that a good thick crop, six inches high, will contain nitrogen and organic matter equivalent to that contained in five tons of barnyard manure, that the nitrogen is quite as useful for the corn plant as that contained in the manure, and besides it is evenly distributed and there is no labor involved in its application. Another advantage of the crimson clover is that it is a spring green-manure crop, thus permitting a return from it in the same season in which it is used. It will pay farmers carefully to study the habits of this plant, and then to introduce it in their rotations as a soil-renovator. If failures occur the cause should be learned and a remedy sought; discouragement should not follow one or two failures—even red clover sometimes fails. It has succeeded in many instances when red clover has failed.

Fig. 671. A heavy growth of soy beans to be used as a green-manure crop. Judgment must be exercised as to whether it is advisable on the particular soil to plow down the entire crop.

Other kinds of clover sometimes used.—There are various other species of clover that possess useful characteristics, though with the possible exception of sweet or Bokhara clover, which is sometimes used in the South, they do not possess advantages superior to those kinds already mentioned. The sweet clover (*Melilotus alba*) is a rank-growing plant, and is common as a weed along roadsides and in waste places. Botanically it is not a true clover.

It is seldom cultivated either for forage or green-manure, though it seems to have the power of acquiring food from sources inaccessible to other plants of the same family. It thrives particularly well on soils rich in lime. Experiments with it in Alabama, Mississippi and Ohio show that, in common with other legumes, it aids in soil-improvement. Its use is recommended only when other varieties do not meet the requirements. Sweet clover may be seeded at the rate of two pecks to the acre.

Fig. 672. Stages in turning under a green-manure crop. Rolling down the crop preparatory to going over it with the disc.

Alfalfa.—Alfalfa belongs to the clover family, and, while one of the most valuable of this class of plants from the forage standpoint, is not adapted so well for use as a green-manure, because of the expense of seeding and the difficulty of securing a stand and because of its comparatively slow early growth. It is a perennial which does not reach its maximum annual growth until the second or third year after seeding. If broadcasted, alfalfa may be seeded at the rate of 25 to 35 pounds per acre; if drilled, 15 to 25 pounds.

The field-pea.—The variety of field-pea that is used for forage, for cover-crop or for green-manuring, is usually known as the Canada field-pea, though the the name includes a number of varieties, as Golden Vine, Prussian Blue, Green Field, Mummy and others, any one of which is satisfactory for the different purposes. This field-pea does not differ greatly in appearance or characteristics from the ordinary garden pea. It thrives well in the more northern states only in the cool, moist weather of early spring and late fall, and consequently is not adapted to sections south of the Middle States. For this reason, as well as because it does not grow well except on good soils, its use as a cover-crop or as a green-manure is limited. Still, there are occasions when its use will meet conditions not provided for so well by other plants. For example, it may be seeded in September, or even early October in New Jersey, periods too late for the seeding of other legumes, and because of its rapid growth make a crop before freezing weather. The crop serves as a mulch during the winter, preventing the wasting of sandy soils due to high winds, and the accumulated nitrogen and organic matter provide readily available plant-food for spring-sown crops. It has proved of great advantage in many lines of farming when the crops are not removed early enough to permit the seeding of crimson clover or other leguminous crop.

It should be seeded at the earliest possible time in spring, and in fall not earlier than August first, at the rate of one-half bushel to two bushels per acre, and the seed well-covered, preferably two to four inches.

Cowpea.—The cowpea reaches its best development in warm climates. A large number of varieties have been developed which are adapted to cooler conditions, so that now it is well distributed even throughout the North, where it is proving one of the best annuals, and is well adaptated to various uses; and the rapid and large development of the plant make it one of the most useful of the legumes for soil-improvement.

The natural tendency of the plant toward variation has resulted in a large number of varieties, though the permanent and distinct ones are comparatively few. When the cowpea is grown primarily for green-manure, then the season during which it grows should determine the variety to choose. It is more difficult to choose varieties for the North than for the South, as the plant has not been so carefully studied in the North. The Whippoorwill, Wonderful, Clay and Red Ripper varieties are well adapted for green-manure, as the longer they grow the larger the crop, except when only two or three months can be given to the growth of the crop.

For green-manure the crop may be sown broadcast at the rate of one to one and one-half bushels per acre, or may be drilled in with an ordinary grain-drill. If the seeding is not made too early,—and in no case should it be made before the soil is thoroughly warm,—broadcast methods are very satisfactory. If, however, the early growth of the plant is retarded, then weeds secure a foothold and it is likely to be choked out.

There is perhaps no other crop that is so generally useful for soil-improvement as the cowpea. In the first place, it grows during the hot summer when it is desirable to have the ground covered, and its long tap-root penetrates into the subsoil, loosening it and making it more porous; and in the second place, the absorption and assimilation of the free nitrogen renders it of great service when the crop is used for forage and only the roots and stubbles are left as additions to the soil.

The cowpea crop may be plowed under while green or it may be left on the surface as a mulch during the winter and plowed under in the early spring. It may be partially grazed and the stubble and roots plowed under. In any case, the improvement of the soil is very marked. When the forage can be used to advantage and the object is gradually to improve the soil, the better plan is to remove the crop either for use as green forage or for hay, as on good soils the stubble and roots will furnish sufficient nitrogen to supply the early needs of a cereal crop. On light soils it is also desirable to remove part of the growth, as the turning under of a very heavy crop of cowpeas would be likely to injure rather than to improve the physical character of the soil. The danger from plowing under heavy green crops is not so marked in the North as in the South, where the temperature range is high for a longer period. On heavy clay soils the improvement in plowing under heavier crops is very marked.

Soy bean.—The soy bean has a strong central root, stiff hairy stems, broad leaves; it somewhat resembles the ordinary bean, though it is larger, taller and bushier. The plants may be dwarf and early maturing, or late and tall, though in no case do they vine as do the vining and trailing varieties of cowpeas. There are a number of varieties. The Green seems to be the variety most generally used. The crop from it varies greatly, according to the season and climate.

This plant resembles the cowpea in many of its characteristics, and, like it, should not be seeded until the soil is warm. For green-manuring it may be seeded broadcast. The quantity of seed per acre will vary from one to one and one-half bushels when broadcasted, depending on how well the seed is covered; when seeded in rows, the quantity of seed may be reduced to one-half bushel or three pecks per acre. The land should be put in good condition, in order that germination may be prompt.

Experience thus far shows that the soy bean is slightly more difficult to handle than the cowpea and the yields are not so heavy, though the plant contains more nitrogen in the dry matter. It has been grown for green-manure purposes when there has been a scarcity of the seed of the cowpea. Many prefer it to the cowpea because the plant is easier to cover completely in plowing; a large crop of cowpeas is particularly difficult to plow under. The decay of the plant will probably be quite as

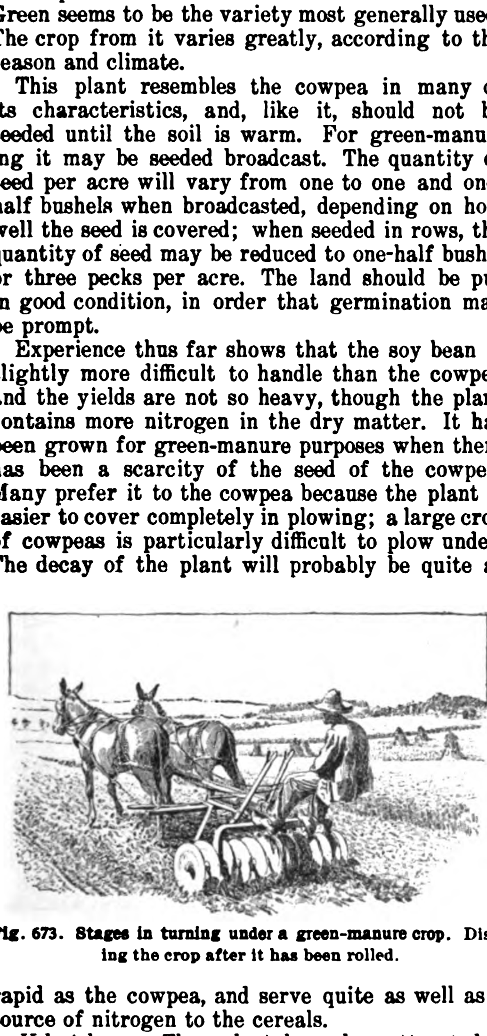


Fig. 673. Stages in turning under a green-manure crop. Discing the crop after it has been rolled.

rapid as the cowpea, and serve quite as well as a source of nitrogen to the cereals.

Velvet bean.—The velvet bean has attracted a great deal of attention lately in the southern states. It is native in the tropics, and has proved successful only in the extreme south. In Florida it has been one of the most useful of the forage plants, and is highly regarded as a green-manure crop. It grows well on light, sandy soil, and the yield is ordinarily about the same as for the cowpea. The season of growth is much longer, and for this reason the seed cannot be matured except in

Fig. 674. Stages in turning under a green crop. The last stage.

the South. The results of experiments conducted in the middle and eastern states show that it is not well adapted to these sections, and does not make as satisfactory a crop for any purpose as the cowpea. The velvet bean is seeded at the rate of one bushel to the acre.

Sand or winter vetch.—This has been grown recently with success in the middle, eastern and southern states. It may be planted either in spring or fall, at the rate of about one and one-half to two bushels per acre. It grows much better on light, poor soils than cowpeas or soy beans, and for such conditions is much superior as a green-manure crop. The cost of seed thus far has practically prohibited its use except when small areas are grown.

Spring vetch will answer the same purpose as winter vetch and probably be more serviceable on light soils, though it cannot be depended on to withstand the winters in the northern states.

Methods of inoculation.—In order to secure the full benefit of the leguminous crops as green-manures, it is necessary to see to it that the proper organisms are present in the soil. This may be accomplished readily by inoculation, or introducing the specific organisms. Experiments show that only a small quantity of soil is necessary to accomplish the purpose. For example, 100 to 200 pounds of soil taken from different parts of a field that contains the organisms, if sown broadcast over an acre which does not contain them, will introduce the organisms, which multiply and distribute rapidly, and soon prepare to do their work for the crop. Once the organisms are present in the soil, there is little danger that they will be destroyed under good conditions of farm practice; and if the crops that are grown on the area which has been inoculated are used as food for farm stock, and the manure used elsewhere on the farm, the chances are that the organisms will be generally distributed, so that the work of inoculation is not a serious matter.

It very often happens that in the growing of such crops as cowpeas and soy beans, the first crop will not show the tubercles on the roots, but that the second one will be well supplied with them, indicating that the organisms are very often introduced into the soil by means of the seed. In some cases seedsmen now make it a practice in harvesting their crops of soy beans and cowpeas to pull them instead of cutting them; then in threshing, more or less of the soil that probably contains the proper organisms is mingled with the seed, and when removed leaves the seed well inoculated. [Cf. Chapter XIII.]

The amount of nitrogen gathered.—It does not follow, however, even when these organisms are present in the soil, that all of the nitrogen contained in the crop of the legume has been gathered from the air, as it has been shown that the plants will preferably take soil nitrogen; and therefore, on good soils, well supplied with nitrogen, the proportionate amount of nitrogen drawn from the air will be much less than will be the case when the crop is grown on soils poor in nitrogen. The exact amount of nitrogen gathered by a crop, therefore, cannot be exactly determined, though it is believed to depend on the character of the soil, whether rich or poor in available nitrogen. Hence, the usefulness of the legumes as a means of acquiring nitrogen is greater when grown on soils poor in this element; these soils are more greatly benefited by the accumulation than those previously rich in the element nitrogen.

The importance of an abundance of the mineral elements.—It has been demonstrated that the proportion of nitrogen gathered by the plant from the air, particularly on poor soils, will depend on the supply in the soil of the other necessary plant-food ingredients. That is, soils poor in nitrogen and often poor in physical character, if not well supplied with the minerals, phosphoric acid and potash, will not produce a large crop of cowpeas or soy beans or any other leguminous plant, because its growth and development depends on the ease with which it may acquire the necessary amounts of these other elements of nutrition. Hence, in attempts to build up poor soils by means of green-manure crops, it is quite as necessary to fertilize with the minerals in order to insure maximum growth as it would be in order to grow any other crop. This is entirely reasonable, as the mineral constituents cannot be secured from any other source than the soil, and they are quite as essential in the complete growth and development of a crop as is the nitrogen.

The point is, that green-manuring does not result in building up and making better a soil that is naturally poor in the mineral constituents. It can contribute only the nitrogen, and that in itself is not a complete food: it is only one of the essential elements.

On heavier soils, overlying strong subsoils, as, for example, clay loams, and which are usually rich in dormant mineral constituents, the practice of growing the legumes may result in building up the soil both in available nitrogen and in available minerals, as these plants have the power of acquiring the minerals from such soils more readily than certain other classes of plants. The roots running deeply in the soil and subsoil gather the mineral food and store it in their larger roots near the surface, where it is available not only from the standpoint of other plants reaching it, but also from the standpoint of its being more readily acquired by them. Such soils may be improved and kept in a high state of fertility by the frequent growth of a renovating crop, whereas on light soils which are poor in all constituents, the improvement will be in proportion to the amount of minerals supplied, as they will measure in a degree, at least, the rate of appropriation of the nitrogen. These considerations are practically true for all of the plants in the group of legumes, though the different plants may apparently differ materially in their rapidity or degree of growth, even on the same soil and without the addition of other materials. The fact remains, however, that genuine improvement of poor soils cannot be expected from the growth and use of green-manure crops alone.

The amount of nitrogen contained in average crops.—While it has already been pointed out that it is very difficult to estimate the quantity of nitrogen that the leguminous crops will draw from the air, the following tabulation shows the nitrogen and organic matter that are contained in an ordinary crop of the various plants:

	Tons per acre green	Nitrogen Pounds	Organic matter Pounds
Cowpeas	6	48	1,920
Soy beans	6	60	2,640
Crimson clover	6	60	2,160
Alsike clover	6	60	2,640
Red clover	6	60	2,400
Canada field-peas	5	50	2,200

If the amounts of nitrogen indicated in the table as contained in a crop that can be harvested were all gathered from the air, there would be an undoubted increase in the fertility of the soil, as the amount of nitrogen gathered is equivalent to that contained in 320 to 400 pounds of nitrate of soda, which would be regarded as a heavy dressing even for vegetable crops. Interpreted in terms of barnyard manure, the nitrogen and vegetable matter would be equivalent to six to eight tons of average barnyard manure. It must be remembered, too, that the yields given are not large, and that they do not include the amount of nitrogen and organic matter that may be contained in the roots and stubble, which, in the case of the clovers, is very considerable.

Experiments have shown that the rapidity with which the organic matter will decay and give up its nitrogen to the cereal plants is such as to make this source of nitrogen compare favorably with that contained in the average commercial fertilizer. The fact that so large an amount of nitrogen is introduced by means of green-manures, whether entirely drawn from the air or not, makes it important to use care, in order to prevent too large an accumulation of this element. The danger, particularly in the case of certain cereal crops and fruits, is that the excess of nitrogen would be likely to cause an abnormal growth of leaf and wood. As in all other lines of farm practice, it is the judicious use of nitrogen that results in maximum returns.

The plowing in of green-manures.

A point that should be clearly understood in the matter of soil-improvement by means of green-manures is the time for plowing down the crop. In the first place, the character of soil exerts an influence on this point. As a broad general rule, there is danger of injury to light soils in plowing down a heavy burden of green material, particularly in warm weather, whereas on heavy soils the danger is very much less, and in fact ordinarily very remote. Hence, the discussion of the influence of the season of growth is worthy of consideration. If the crop which is intended for green-manure matures rather early in spring, then the time of plowing under must be governed by the purpose of the crop which follows, as its development will be materially influenced by the operation. For example, consider rye, representing the class of "nitrogen-consumers." This crop makes a rapid early development, and, if allowed entirely to mature, it not only draws heavily on the available food constituents of the surface soil, but rapidly and often completely exhausts it of moisture. Therefore, if plowed down in its mature state, it will result in leaving between the surface and the subsoil a mass of vegetable matter not readily broken down, thus cutting off the connection between the surface and the reservoir of water lying below. Should dry weather follow, the decay will be very slow, and the succeeding crop will have only the food and the moisture that are contained in the surface soil turned over, and from this the available food and the moisture have been largely extracted by the maturing of the large crop of rye.

The principles involved here are practically the same for crops of a leguminous character. For example, crimson clover that has been seeded in corn, or in orchards for the purpose of accumulating nitrogen, also prevents mechanical losses and contributes to the improvement of the physical character of the soil. Still, the time of plowing down the crop is of the very greatest importance, not only in its influence on the character of the soil itself but on the growth of the subsequent crop. Should the crop mature, and the weather conditions be entirely favorable, and should there be sufficient moisture and warmth, no danger may be apprehended in allowing it to mature; but if the primary purpose is not to secure the full benefit of the clover crop, but rather to ensure the growth of the succeeding crop, whether it be corn or peaches, pears or plums, then the use of the crop, its time of plowing down, should be made when it will not interfere with the primary purpose in its growth.

Fall green-manure crops.

In the case of crops that are grown during the summer, the considerations in reference to soil still hold true, and even in a greater degree, since crops plowed down during the summer are more liable to rapid fermentation than those plowed down in the spring. Trouble from soil acidity may result from plowing down, in the late summer or fall, crops grown in the summer; yet the results of such practice will depend considerably on the time that they are turned under and the character of the weather that follows. Cowpeas that have been seeded in July and have grown through August and part of September may be plowed down in late September or early October without any danger to the succeeding crop or soil, unless the weather conditions are very unfavorable, as dry and hot, in which case the dangers pointed out in the turning down of the rye in the spring in its mature state would be likely to follow. If the weather should continue moist and hot the rapid decay of the vegetable matter will be likely to result in a too rapid fermentation, probably inducing acidity of the soil; this would not be likely to be a real danger except on very light, open soils, On heavy clay soils, where the texture is more dense, the tendency would be to prevent the too rapid entrance of air, and thus cause a more uniform decay. When the crop is very large, and when the conditions pointed out here are anticipated, the better practice will be to remove the burden of crop, in part, at least.

The use of lime.

It is desirable, whether in the spring or fall use of the manure crops, to see to it that there is sufficient lime in the soil to assist in the fermentation, as well as to neutralize acids that may be developed. It is not necessary that it shall be applied in all cases, since the application of, say, twenty-five bushels of stone lime per acre in a rotation once in four years, would be likely to meet all the needed requirements for lime. If these suggestions are observed in reference both to soil-inoculation and to the plowing in of the green crops, there is no question as to the advantages that may be derived from the practice. It will result not only in building up soils poor in nitrogen, but will contribute materially to the improvement of their physical character, their water-holding capacity and their consequent crop-producing power. On soils rich in potential fertility, the continued and judicious use of green-manures will materially improve the mechanical character of the soil and will be very influential in the maintenance of fertility without large additions of the minerals, phosphoric acid and potash.

Literature.

The literature on the use of green-manures in soil-improvement is very scant. The following publications bear on the subject: Zwischenfruchtbau auf leichtem Boden, Schultz-Lupitz, Berlin, 1901; Bulletin No. 102, Pennsylvania Department of Agriculture, Harrisburg, E. B. Voorhees, September, 1902; Bulletin No. 120, the Alabama Agricultural Experiment Station, Auburn, J. F. Duggar, April, 1902; C. Harlan, Farming with Green-Manures, Philadelphia.

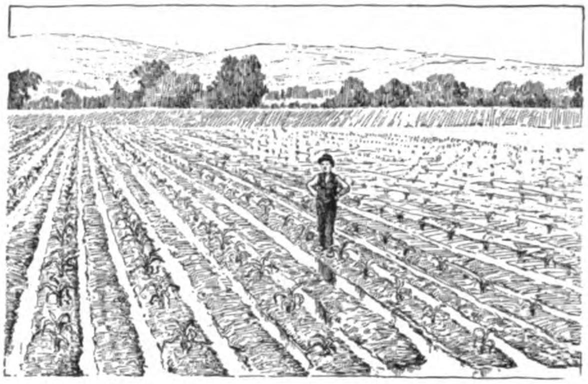


Fig. 675. Irrigating with sewage in June.

THE UTILIZATION OF CITY WASTES ON THE FARM

By *M. N. Baker*

There are six main classes of city wastes that may be utilized on the farm: (1) Sewage. (2) Garbage. (3) Stable manure. (4) Street sweepings. (5) Ashes. (6) Slaughter-house refuse. In the following discussion of these wastes it should be borne in mind that their theoretical value is largely offset by the cost of collecting them within the city, drawing them to the farm and, in some cases, preparing them for utilization on the land.

Fig. 676. Corn in July, irrigated with sewage.

Sewage.

Sewage consists of human dejecta, dishwater, other household wastes, and generally of manufacturing wastes as well, conveyed through sewers to a common point of disposal. Every 1,000 parts of sewage is composed of 998 parts of water and only two parts of solid matter; of the latter, half is organic matter and half inorganic or mineral matter. Not only is the fertilizing value of the sewage limited to the one part per 1,000 of organic matter, but, in addition, this organic matter is not directly available for plant-food. To utilize the fertilizing value of the sewage the latter is applied to the land in practically the same way that water is applied in ordinary irrigation; that is, by means of ditches and sub-ditches, or, when the slope permits, by flooding the land with sheets of sewage distributed from overflow ditches. Almost any crop requiring or able to stand large quantities of moisture may be grown under sewage, providing the sewage is not applied directly to parts of the plants used for human consumption without thorough cooking.

Sewage farming, or broad irrigation, is practiced but little in the United States, and that almost wholly in the arid West, where the main object is to utilize the moisture rather than the fertilizing value of the sewage. The use of sewage as a substitute for water in irrigation might be practiced to advantage throughout all parts of the country which suffer periodically from scanty rainfall, and it might often be practiced as a temporary measure during droughts even in the humid regions. When local conditions demand both purification of the sewage and a conservation of moisture, the advantages of sewage irrigation are doubly great. Sewage farming is practiced extensively in Great Britain and near Paris, Berlin and other foreign cities, with the primary object of purification alone. The sewage farms of each of the cities named cover many thousands of acres of land, and a number of British cities have sewage farms ranging in size from less than 200 to 2,000 acres. Among the notable British sewage farms may be mentioned those of Nottingham, Leicester and the Aldershot Military Camp. The Leicester farm is notable because of the difficulties which have been encountered in applying sewage to dense clay land, through which the percolation is so small and the purification so little that it is necessary to collect the sewage in ditches and apply it to the land for a second time and sometimes for a third time.

All things considered, the best American example of a sewage farm is at Pasadena, Cal., where water for irrigation is scarce and costly and where the sewage of the city is conducted a number of miles to a farm on which walnuts are raised, and, it is

Fig. 677. Field harrowed and ready for flooding.

said, with considerable profit. Part of the farm has recently been planted with orange trees, which receive the sewage when it cannot be used in the walnut grove. The sewage of Los Angeles was used extensively for many years by Chinese market-gardeners with apparent profit, but the Chinamen surreptitiously applied the sewage to garden stuff that is eaten uncooked, which fact, combined with the rapid extension of the city to occupy the sites of many of the gardening areas, has greatly lessened the utilization of sewage in that city. At one time or another the sewage of a dozen or more other western cities and towns has been used for irrigation. Sewage farming was also practiced for some years by the Pullman Company, at Pullman, Ill., now a part of Chicago. Crops of various kinds have been raised on the intermittent sewage filter beds of South Framingham, Mass., and Plainfield, N. J., where the sewage was applied at a rapid rate to artificially prepared beds of sand, quite different from sewage farms in character.

Fig. 678. Raking off sludge deposit (more deposit than usual).

On the British farms, dairying and stock-raising are extensively practiced, and market-gardening also. Several crops of Italian rye-grass are raised yearly on sewaged land, and fed to dairy or other stock; and sewage is sometimes applied to pasture-land. Mangel-wurzels and Swede turnips are staple sewage-farm crops. These and other crops, such as oats and barley, are frequently grown in off years, or as rotation crops to give the land rest from receiving sewage. Figs. 675 and 676 show sewage irrigation.

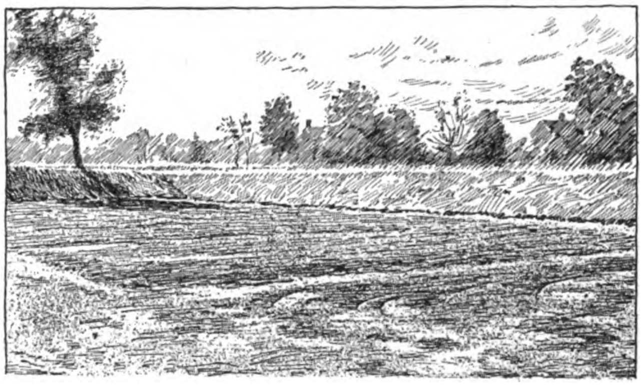


Fig. 679. Sludge deposit sprinkled with lime ready for raking.

When the volume of sewage is large, compared with the area of land available, or when the land is heavy and not naturally well drained or easy of drainage, it may be necessary or advisable to submit the sewage to preliminary treatment for the removal or reduction of solid matters which would clog the surface of the land. Chemical treatment, with sedimentation, will remove a large part of the solid matter; plain sedimentation will remove less, and screening or straining still less. If the sewage is passed through a long, narrow and relatively shallow tank or tanks, say 20x100 feet, by 7 or 8 feet deep, so that it will take twelve to twenty-four hours to make the journey, 30 to 50 per cent of the solid matter will be removed; some will be transformed into gases, some liquefied and made more susceptible to oxidation, and some will remain in the tank as sediment or sludge. By this means less solid matter is passed to the sewage farm and most of what goes is more easily converted into plant-food than when applied in its crude state. Such a tank is called a septic tank, and relies for its efficiency on anaërobic bacteria, or those that break down organic matter in the absence of air. The conversion of organic matter by sewage farms is also due to bacterial action, the bacteria here being known as nitrifying organisms, or those changing organic matter from albuminous forms to nitrogen compounds, the nitrogen being united with mineral salts. [For another discussion of septic tanks, see page 297.] Sewage filter beds between croppings are shown in Figs. 677–680.

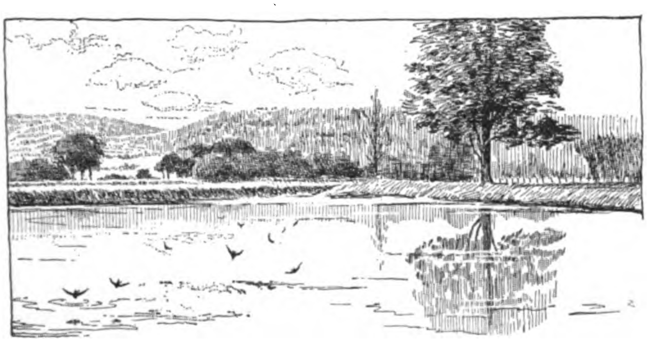


Fig. 680. Sewage filter, flooded with sewage.

Besides the utilization of sewage on farms, it is well known that night-soil from privies can be employed in like manner, but by different methods: either after composting, or after being dried or otherwise treated so as to make some form of commercial fertilizer or its general equivalent.

Garbage.

Garbage, or the food wastes of the kitchen and the table, supplemented by the like wastes of hotels and restaurants, and by market refuse, contains ammonias and phosphates of considerable fertilizing value, combined with inert organic matter, some mineral matter, and 75 to 90 per cent of water. If the garbage proper is kept separately from ashes, tin cans, broken glass and crockery, it may be applied directly to the land as a green-manure, enriching the soil to some extent, but perhaps doing more good by changing the texture of either clayey or sandy soils. When used as a green-manure it would probably be advisable to deposit the garbage in shallow trenches and cover it with six to eight or ten inches of soil, letting the land lie idle for a year or sowing it with a crop that does not require cultivation. In any event, the garbage should not be allowed to lie exposed on the surface, at least in the vicinity of dwellings or highways, lest it give rise to a nuisance.

Some British cities with farm lands of their own think that the application of garbage to land is a profitable proceeding, when the haul is not too long; but in this country, the only financial reason for such a method is that it may sometimes be the cheapest means of garbage disposal available to a city. There is little or no practical data for judging the value of crude garbage as a green-manure, but it is doubtful whether any farmer could afford to do more in return for garbage than to provide the labor required in digging the shallow trenches, leveling the garbage dumped therein by the city wagons, and covering it with dirt.

An alternate means of disposal of crude garbage is to feed it to hogs. When collected and fed while in a fresh condition there seems to be little danger that garbage will harm hogs, although it was at one time thought, and some still hold to the belief, that garbage-fed hogs are particularly liable to contract trichinosis. Obviously, a garbage disposal plant combined with a hoggery would have to be carefully located and operated to guard against a local nuisance from both the garbage and the hogs. The nuisance would be in the nature of bad odors, which would be no more injurious to the public health than any other unpleasant smells. Feeding garbage to hogs has been tabooed in the past, but some health officers in the New England states have come to its defense of late. On the whole, the practice is not to be commended, except when farmers collect limited amounts every day or two and feed the garbage directly to their own hogs.

Under no conditions yet proposed should city garbage be fed to milch cows.

The wholesale utilization of garbage can be best effected by the so-called garbage-reduction process. In this the garbage is first steamed or treated with a solvent, like naphtha, in air-tight tanks, for the extraction of the grease that it contains. After the grease is eliminated, and with it much of the water, the tankage is dried and reduced to a powdery or coarse meal or bran-like condition. This dried tankage contains small percentages of plant-food, and is enriched by the addition of further matter of the same character; in other words, the dried tankage serves as a base for commercial fertilizers. If dead animals and slaughter-house and meat-market refuse are reduced with the garbage proper, the fertilizing value is correspondingly increased; old bones can also be utilized advantageously with garbage. The garbage of New York, Philadelphia, Baltimore, Washington, Cincinnati, Cleveland, Buffalo, Syracuse, Boston, New Bedford and many other cities of large and medium size was being utilized in reduction plants in 1905, all of which are owned and operated by private companies, except the one at Cleveland, which was bought by the city early in that year. These companies are paid bonuses of varying amounts by the several cities. When garbage, unmixed with ashes and other foreign matter, is burned in furnaces or cremated the resulting ash has considerable theoretical and probably a fair actual value as a fertilizer. It has been so used but little, however. British refuse destructors consume ashes and all manner of refuse besides garbage, and produce a residue which is mostly cinder and clinker, and is thus non-utilizable for agricultural purposes. Most American garbage furnaces burn garbage, paper and other combustible refuse, but do not receive ashes.

Stable manure.

Stable manure and its possibilities on the farm scarcely need be considered here, further than to call attention to the vast quantities produced annually in cities great and small, and the sanitary demands for quick removal from the city and for dry storage of such as cannot be taken away or is not so removed. [See the articles on pages 490 and 500.]

Street sweepings.

Street sweepings are mixed with so much dirt as to be of less value than might be expected. They might often be saved, however, particularly for application to light, unfertile lands, or to lands that might be improved in physical condition.

Ashes.

When ashes originate from wood, they have well-recognized fertilizing value. They should be kept dry until used. Most city ashes, however, come from coal, and besides their almost complete lack of fertilizing value, contain so much cinder and unburned coal as to make them a nuisance if applied to land, even if tin cans and the like were not dumped into the ash barrel. If properly screened, coal ashes might often be used advantageously to lighten heavy clay lands. The unburned coal would supply fuel to drive the screening apparatus, with a surplus for other purposes, while the rejected cinders might be used for concrete.

Slaughter-house refuse.

Slaughter-house refuse, when produced on a large scale, is utilized on the premises by a variety of methods which do not call for description here. Certain of the wastes are manufactured into fertilizers, substantially as in garbage-reduction plants; but slaughter-house refuse has a higher fertilizer value than has garbage. The wastes of small slaughter-houses may be sent to garbage-reduction plants or garbage crematories, according to which is available.

Economic considerations.

It will be seen that few of the city wastes can be used on the farm without the intervention of the engineer, the manufacturer, the contractor or the city itself, and that in all cases the cost of transporting the wastes to the farm, to say nothing of preparing them for use, is a factor that cannot be neglected without a risk of economic failure. Notwithstanding this, the possibilities of utilizing these wastes are so great that they deserve far more consideration than they have yet received from the American people. So far as the cities themselves are concerned, such utilization should be considered as a means of reducing the cost of waste disposal, rather than making a profit from it.

The farmer should take a conservative view of the subject and choose intelligently between city wastes or their products and other materials for increasing the productiveness of his land. The subject is primarily not an agricultural question and therefore need not be given extended discussion here.

Literature.

The literature on the utilization of city waste on the farm is very meager, at least with reference to American conditions. There is practically no available literature on this phase of garbage disposal in America, except articles in the technical press, and papers read before various societies. For the use of sewage and sewage disposal, the following publications should be consulted: Sewage Disposal in the United States, by George W. Rafter and M. N. Baker, New York, D. Van Nostrand Company, 1904. Sewage Irrigation, by George W. Rafter, Water-Supply and Irrigation Papers, Nos. 3 and 22, Washington, D. C., published by the United States Geological Survey, 1897 and 1899. (Figs. 675–6 adapted from Gavett.)

CHAPTER XV

ALKALI SOILS

ALKALI SOILS are usually characteristic of arid regions. They may occur naturally, or as the result of irrigation. We have learned in Chapter X that soils are formed largely of disintegrated rock. This rock contains many soluble materials. If the region is humid, these soluble materials are carried off gradually in the drainage waters. They find a resting-place in bodies of water that have no outlet, as in the ocean, the Dead Sea, Great Salt Lake, and these waters become "salt." These bodies of water are constantly receiving more of the chemical salts, and evaporation may condense the solution. If these waters are finally removed, salty land may remain; or drainage waters may carry the salts to other outlets. Such lands may or may not be alkaline, as the term alkali land is commonly understood. The present alkali regions are far removed from the ocean, and are the result of arid conditions. When the region is arid, there is likely to be no drainage, and the water of rainfall is lost through evaporation, and the soluble materials are left at the surface. If irrigation is practiced, more of the materials are taken into solution, more water is evaporated from the surface and more of the materials are left there.

Alkali is commonly made up of salts of sodium, magnesium, calcium, and sometimes of potassium. These salts are mostly carbonates, chlorids and sulfates. Rarely does an alkali soil contain only one kind of alkali, although such soils are popularly divided into "black alkali" and "white alkali." Black alkali is carbonate of sodium, a salt which, in a refined condition, is known as sal-soda or washing-soda. This is the most dreaded. White alkali includes all the other kinds of salts.

It is not unusual to find alkaline and salty spots in lands in semi-humid countries, particularly in seasons of high evaporation and little drainage. The typical alkali soils, however, are regional. They are characteristic in our arid West. It is probable that there are more than a million acres of such lands in

the United States. Inasmuch as irrigation does not also provide underdrainage, the area of alkali lands tends to increase as irrigation increases. It is one of the problems of modern agriculture to prevent this increase; and it is another problem to find some means of utilizing alkali lands. The articles that follow explain the problems and the means of attack.

METHODS OF RECLAIMING ALKALI LANDS

By *Thos. H. Means*

Alkali land is sometimes natural, cultivation never having been attempted. The greater part, however, is land that has accumulated alkali through the irrational practices of the irrigator. Much of it that was once under cultivation, and that had considerable time and money invested in it in leveling and preparing it for crops, through rise of alkali is now idle, though lying under irrigation canals and in every way favorably situated for irrigation. Other areas are now only slightly damaged, but are gradually becoming more charged with alkali, and each year productiveness is lessened; still other large areas of good land are threatened with destruction unless there are changes in the methods of irrigation and cultivation. Other countries have had similar trouble,—Egypt, India, Algeria, Italy, France; in fact, wherever irrigation is practiced the problem is recognized, constituting a question of the greatest public concern. Large areas of once fertile lands now lie barren, and some of the countries of oldest civilization are now desert, due in part to the "rise of alkali."

How lands become alkaline.

The normal condition of arid lands is illustrated in the table below. The first part gives the percentage of total soluble salts in two soils from central Montana where neither soil originally contained enough alkali within the zone of root action to be detrimental. The second part shows the condition of these soils after a few years of judicious irrigation, and the third part displays the condition after a few years of irrigation without drainage:

Table Showing Percentage of Alkali in Soils.

Depth	Unirrigated		Irrigated		Over-irrigated	
	Sandy loam	Clay	Sandy loam	Clay	Sandy loam	Clay
First foot . . .	.04	.04	.04	.10	.79	.76
Second foot . .	.04	.04	.05	.07	.92	.71
Third foot . . .	.03	.05	.04	.08	.94	.63
Fourth foot . .	.03	.20	.05	.08	.79	.61
Fifth foot . . .	.05	.33	.06	.08	.52	.59
Sixth foot . . .	.06	.34	.05	.16	.52	.19
Seventh foot . .	.06	.25	.06	.21	.36	
Eighth foot . .	.17	.25	.07		.36	
Ninth foot . . .	.24	.28	.05		.29	
Tenth foot . . .	.24		.05			
Eleventh foot .	.21		.07			
Twelfth foot . .	.12		.07			
Thirteenth foot .	.16		.07			
Fourteenth foot .	.22		.07			
Fifteenth foot .	.18		.07			

This table shows that in the natural condition of these two very different soils there is little alkali in the surface three feet of soil, but that below that depth there is sufficient alkali to do serious damage if it is allowed to rise. The second part of the table shows that the soluble matter readily leaches out of the sandy loam, while the clay soil retains a larger part of the salts. The third part of the table gives the conditions as found in alkali flats after over-irrigation has been practiced a few years and the rise of alkali has occurred.

To understand better the movements of alkali, let us consider what happens when water is applied to a soil that contains soluble salts. When water is first applied to a soil it is drawn downward by two forces,—gravity and surface tension (capillarity). The most rapid movement is caused by gravity, pulling the fluid downward through the larger spaces between the soil grains. The spaces or pores in a soil are of two kinds,—the capillary spaces, or those so fine that they will retain water against gravity, and the larger or gravity spaces that drain as soon as the source of water is cut off (Fig. 681). These larger spaces are made by worms or animals in burrowing, or are cracks resulting from shrinkage in drying, or are cavities left by decayed roots. The most rapid movement takes place down these pores, the first film of water dissolving the readily soluble salts. Capillarity, acting in the finer pores, draws into them water from the front of the wave, and in consequence the larger part of the salts is drawn back into the capillary spaces. As soon as these are filled, nearly all motion in them ceases, the water, however, continuing to move downward in the large pores under the action of gravity. A soil that puddles has no large spaces, which accounts for the slow movement of water through it.

If the supply of water is maintained at the surface, the water continues to run through the larger spaces and washes them free of salt. The larger part of the salt, however, has been drawn into the capillary pores by surface tension, and is removed from them only by diffusion into the channels of rapid flow. Thus it happens that after the first flush of water passes through an undisturbed soil, further leaching removes soluble salts slowly.

When the supply of water from the surface is turned off, the gravity spaces drain off the excess water, and evaporation begins at the surface. Water is drawn upward by capillarity to replace that lost by evaporation. It is the water that was drawn into the capillary pores, or that which contains the most of the soluble matter, that now moves upward. It thus appears why alkali seems to rise so much more rapidly than it moves downward.

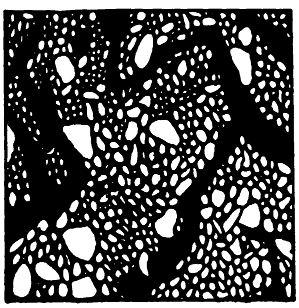


Fig. 681. Undisturbed soil showing large openings through which water flows under action of gravity, and smaller pores in which movement is by capillary forces only.

A second flooding washes out the gravity spaces, again removing part of the alkali, but leaving much of it in the capillary pores. Frequent flooding, alternately filling and emptying the larger spaces, is, therefore, the most rapid method of removing an excess of soluble salts.

In the irrigation of soils that contain alkali, it often occurs, notwithstanding that for several years the soil has been heavily irrigated, that alkali remains in the subsoil. If the irrigation is stopped, the upward capillary movement begins and alkali accumulates at the surface. Or, if the subsoil fills with water so that the level of standing water is so close to the surface that the capillary action continuously raises this water to the surface, it may be that the upward movement by capillarity will carry to the surface, in a given period, more alkali than the irrigation waters can wash down. When this condition occurs and the accumulation at the surface begins, the land will speedily be ruined unless there is some change by which this upward movement of the salt is checked. The problem of reclamation of alkali land therefore resolves itself into finding some practicable means of turning this movement into a downward direction and enabling irrigation to remove the surplus of salts.

The methods employed in reclaiming alkali lands may be divided, for convenience, into the following heads, and it is proposed to discuss them in order in a brief and summary way: (1) Chemical correction, (2) growing of resistant plants, (3) cultivation, (4) removal of alkali, (5) underdrainage and leaching.

Chemical correction.

The first method that suggests itself is to change the salts chemically into a compound either insoluble or inert. There are no methods known for accomplishing this with all salts occurring in alkali soils. In the case of sodium carbonate a chemical reaction is possible which changes this alkaline salt into one chemically neutral and consequently much less harmful. This process, originally proposed by Hilgard, consists in applying gypsum or land-plaster to the soil. The sulfate of lime reacts with the sodium carbonate to produce sodium sulfate and calcium carbonate. The latter compound is the well-known limestone, beneficial to soils; and the sodium sulfate is relatively much less harmful than the carbonate. For each part of sodium carbonate, 1.3 parts of sodium sulfate will be formed. One-tenth of one per cent of sodium carbonate is too much for ordinary crops; the change into sodium sulfate will make 0.13 per cent of sodium sulfate, or less than one-third the amount of that salt necessary to injure plants. Thus, when the black alkali is unaccompanied by harmful quantities of other salts, gypsum will be found effective in reclamation.

The following table shows the quantity of gypsum required to neutralize sodium carbonate in an acre-foot of soil:

Per cent sodium carbonate	Gypsum per acre-foot[1]	Per cent sodium carbonate	Gypsum per acre-foot[1]
Per cent	Pounds	Per cent	Pounds
.01	640	.06	3,840
.02	1,280	.07	4,480
.03	1,920	.08	5,120
.04	2,560	.09	5,760
.05	3,200	.10	6,400

[1] An acre-foot of soil weighs 4,000,000 pounds.

Very often the black alkali is accompanied by other soluble salts, and the change in kind of salt brought about by the gypsum leaves more white alkali than plants will stand. The economic use of gypsum is therefore restricted to localities having only small amounts of total soluble salts. As a general rule, drainage can be properly applied and the land freed of both black alkali and white alkali at less expense than by the application of gypsum. Gypsum costs $4 to $10 per ton in the regions where it is needed in black alkali reclamation, and when it becomes necessary to apply sufficient to neutralize 0.1 per cent of sodium carbonate in two or three acre-feet of soil per acre, the cost is seen to be prohibitive.

Growing of resistant plants.

Some plants of great use to man are more or less resistant to alkali salts, and under certain conditions their growth can be undertaken with profit.

The growing of resistant crops on alkali land is always attended with risk, for should there be any change in existing conditions a further rise of alkali may bring to the surface more salt, preventing all growth. In the central valley of California, where drainage has not been attended to, orchards are frequently damaged by alkali. Alfalfa is then planted because it can withstand more salts than the tender varieties of fruit. Further increase in the amount of salt causes the loss of the alfalfa and the owner resorts to Bermuda-grass; this in turn gives way to salt-grass, and that eventually succumbs, leaving the ground bare or supporting a few alkali weeds, valueless for feed.

The statement is often made that some crops can be grown, such as sugar-beets, that absorb so much alkali that they will in a few years remove sufficient salt to permit the growth of any crop on the land. An ordinary crop of sugar-beets will remove less than 2,000 pounds of alkali salt from an acre, and when the amount of salts is placed at the extreme limit of one per cent of the soil, it will require ten years to remove sufficient alkali to permit the growth of the more tender plants. The amount of salts removed by the plants in the form of ash ingredients is therefore relatively small. That removed or washed into the deep subsoil by irrigation may be very important.

Lands heavily charged with alkali have been farmed profitably by the use of such crops as sorghum and kafir corn. In Arizona land is deeply furrowed, water is run down the furrow and sorghum is planted in the bottom of the furrow. The alkali creeps up on the ridges and there remains while the roots seek the soil under the furrow that has been washed free from salt.

[For a further discussion of alkali in relation to plants, see the article by Kearney, following.]

Reclamation by cultivation.

Any method of cultivation that lessens the rate of evaporation from the surface of the soil will help to prevent the accumulation of alkali. Surface mulching, frequent cultivation, application of manure, and the growing of plants that shade the soil, all tend to reduce evaporation; and when there is any alkali in the subsoil which would tend to come to the surface, these methods will either delay or entirely prevent its rise. Such measures must be considered as preventive rather than remedial, for when alkali has already accumulated at the surface mere cultivation or mulching will not ordinarily insure the growth of crops.

When the alkali is all accumulated at the surface of the ground and is not in too large quantity, it is often possible to grow crops by deep plowing and frequent cultivation. Deep plowing turns the alkali well into the soil and mixes it with such an amount of soil as to dilute the crust and render it less harmful. Frequent cultivation then prevents the rise of alkali to the surface until the crop has had time to establish itself and grow beyond the very tender period.

Reclamation by removal of alkali.

There is only one way of reclaiming land permanently, and that is by removing the alkali and making such conditions that no further accumulations from any source are possible. One writer has suggested that the alkali be scraped up when it comes to the surface and carted away. The expense of this is great, and it is generally found that immediately a second accumulation forms by rise of the alkali yet in the subsoil. Such a method is faulty, because it does not remove the cause of the rise of alkali, and as there is practically an unlimited supply of the salts in the deep subsoil or being formed by the weathering of the soil particles, it is not likely to succeed.

A very popular method,—that of flushing water over the surface, washing away the crust of alkali, —seldom succeeds, for the same reason: it does not remove the cause of the accumulation of the crust. This method is furthermore of little value, because the first wave that runs across the field dissolves the alkali crust and is absorbed into the soil, leaving the fresh water behind to pass on over the field. As soon as the surface is dried, this absorbed alkali again comes to the surface to form a crust.

A third method is that of leaching the land. To leach soil there must be an outlet below by which the water can escape,—that is, there must be good underdrainage. Sometimes the natural underdrainage is good, so that to bring the land into a sweetened and fertile condition it is necessary only to wash it thoroughly with fresh water, the natural drainage drawing out from below the saline leachings. Frequently leaching is attempted when the level of standing water is already too close to the surface of the land. The water then has no escape below and can only fill the soil and make a bog of it. The alkali may be washed down a few inches, but there is no permanent removal of the salt and reclamation is not effected. As soon as the surface is dried, evaporation draws the salt to the top of the ground again.

Underdrainage and leaching.

Underdrainage and leaching combined form the one method of reclaiming alkali lands that can generally be recommended. We have found that the alkali moves upward in the soil by capillarity, and that when the standing water is so close to the surface that the capillary powers can draw the water to the top of the ground, the accumulation there becomes rapid. Some soils have greater capillary powers than others and are able to raise the water higher and more rapidly. On such lands drainage needs to be deeper. In studying a district suffering from alkali it becomes necessary to determine for each kind of soil the minimum depth at which water can be allowed to stand, and arrange the drainage ditches or tile to keep the water below this limit. In some soils this depth may be three feet, in others four or more feet. Drainage to any less depth will be ineffective, or will only partially remedy the evil. With drainage conditions properly established, the cause of the accumulation of alkali at the surface is removed. If the land is then heavily irrigated, the alkali will be leached out and carried away by the underdrainage.

Leaching is best accomplished by building dikes around the land in as large areas as possible, and covering with water to a depth of three or four inches. This is allowed to soak in and a second flooding applied, and so on until the land is sweetened. Occasional stirring of the soil between floodings will help to prevent puddling, so likely to occur when water stands on land during hot weather. If some crop can be grown that will stand almost constant flooding, it will help the reclamation by keeping the soil in better physical condition. There are a few crops which permit heavy flooding, such as water grass (*Leptochloa fascicularis*), barnyard grass (*Panicum Crus-galli*), rice, and certain sedges (valuable for making matting and the like). One of these should be grown if possible. The land should never be dried to put in a crop that will not stand flooding until the reclamation has been nearly completed, for as soon as evaporation begins at the surface any alkali within reach of the surface by capillarity begins to come up. It is therefore a mistake to undertake to grow crops that require only ordinary amounts of water until the alkali has been washed below the point from which it can be raised by capillarity. (Figs. 682, 683.)

Efforts at alkali reclamation.

Alkali land reclamation has probably been entered into more systematically in Egypt than in any other country. Nearly 250,000 acres of land more or less charged with alkali have been returned to a fertile condition in that country in ten years. The alkali lands of Egypt owe their condition largely to lack of drainage and to abandonment. The greatest areas of salt land lie in a fringe around the delta at elevations below 20 feet. Left idle after the Arabian Conquest, this once fertile area was flooded by the Nile and by the sea, and evaporation in the hot sun served to concentrate at the surface the small amounts of alkali once distributed through the subsoil. In Upper Egypt, land abandoned since 1860 has accumulated sufficient alkali to be worthless. The establishment of drainage and leaching by heavy flooding has returned large areas to a fertile condition, and there are now beautiful fields of cotton, corn and clover returning as much as $75 per acre each year in rent, where ten years ago nothing would thrive but the most worthless saline vegetation. (Fig. 683.)

In the United States, no systematic attempts have been made to reclaim alkali lands, primarily because of the large areas of good land which can be had. There are areas, however, where alkali lands exist with water for irrigation and where good land cannot be secured. In such places, alkali land reclamation is to be recommended if the value of reclaimed land is sufficient to warrant the expense of draining and leaching.

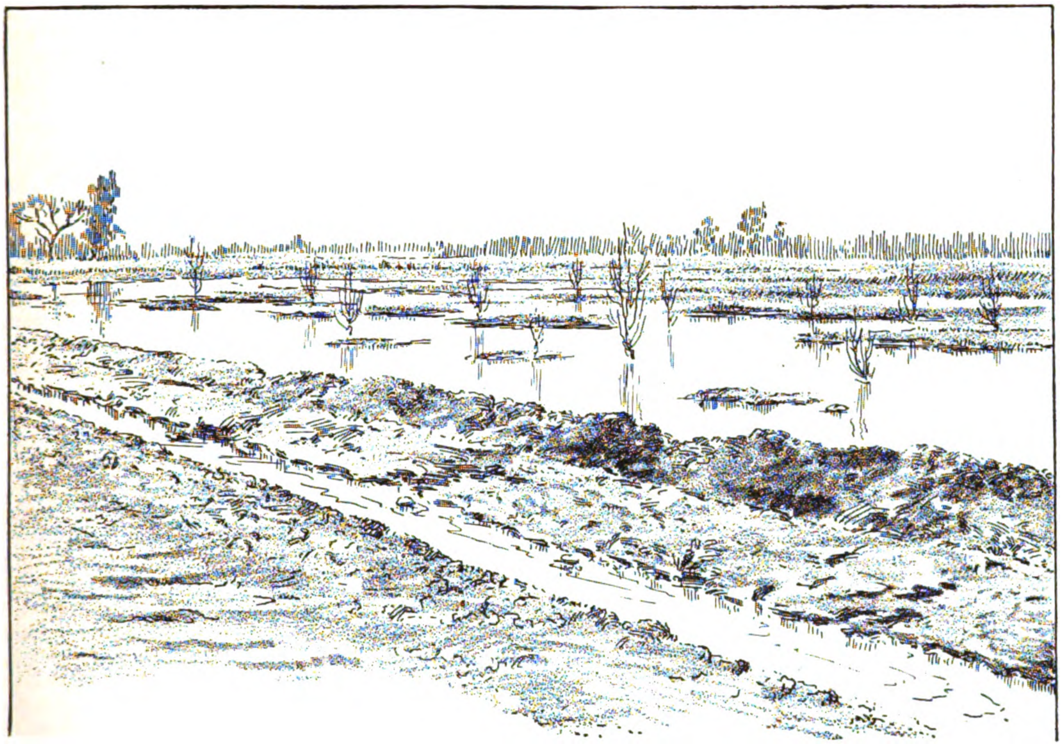


Fig. 682. Flooding tile-drained land to remove black alkali. Fresno, California.

In order to determine the feasibility of reclaiming alkali land and to discover its possibilities in the irrigated districts of the arid West, the Bureau of Soils of the United States Department of Agriculture in 1902 inaugurated a series of demonstrations. Tracts of land were selected near Salt Lake City, Utah; Fresno, California (Fig. 682); North Yakima, Washington; Tempe, Arizona; and Billings, Montana. These tracts of 20 or 40 acres were prepared for basin irrigation, and tile were laid at 50 to 200 feet apart and three to five feet in depth, depending on the character of the soil. Large volumes of water were used in irrigation and everything was done to facilitate leaching the soil. The following tables show the amounts of salt removed by drainage waters and the amount remaining in the soil, from the tract at Salt Lake City:

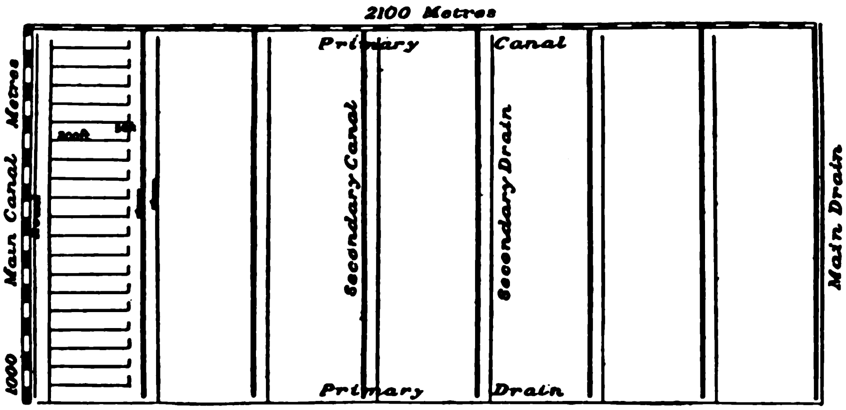


Fig. 663. Plan showing arrangement of irrigating canals and drainage ditches in which the secondary drains run alongside the secondary canals, thus taking up the water lost by seepage from canals in addition to the drainage water from the land itself. This plan is followed in reclaiming alkali land in the Nile delta, Egypt.

TONS OF ALKALI IN SOIL, FORTY-ACRE RECLAMATION TRACT, SALT LAKE CITY, UTAH.

Depth	Sept., 1902	May, 1903	Oct., 1903	Oct., 1904
First foot .	1,363	499	101	38
Second foot	1,540	650	183	128
Third foot .	1,766	1,066	330	212
Fourth foot	1,982	1,265	607	500
Total . .	6,651	3,480	1,221	878

ACRES OF LAND WITH DIFFERENT PER CENT OF ALKALI, FORTY-ACRE RECLAMATION TRACT, SALT LAKE CITY, UTAH.

Per cent alkali in soil	First foot		Second foot		All four feet	
	Sept., 1902	Oct., 1904	Sept., 1902	Oct., 1904	Sept., 1902	Oct., 1904
	Acres	Acres	Acres	Acres	Acres	Acres
.0 .2	0.0	39.0	0.0	27.6	0.0	23.6
.2 .4	3.0	0.0	0.4	8.2	0.9	7.1
.4 .6	3.3	0.0	2.3	3.2	1.9	3.6
.6 1.0	10.7	0.0	8.0	0.0	7.2	2.2
1.0 3.0	16.8	0.0	19.7	0.0	19.3	2.2
3.0+	5.0	0.0	8.4	0.0	9.5	0.0

These two tables show that the original soil contained over 2 per cent of alkali salts to a depth of four feet, and that at the beginning of the experiment there were only three acres containing less than 0.4 per cent of alkali in the first foot. After two years' irrigation, in October 1904 all of the land contained less than 0.2 per cent of alkali in the first foot, and there had been removed from the tract 87 per cent of the alkali originally present. The cost of tile draining was about $16 per acre. Other expenses chargeable to reclamation were, hire of man for irrigating six months each year at $40 per month, and two plowings at $1.50 per acre each. The total expense of reclamation, therefore, was $31 per acre. The land just before reclamation was sold for $8 per acre, and at the end of the experiment was worth $75 to $100 per acre, an increase in value of $67 to $92 per acre, brought about by the use of $31 per acre.

Near Fresno, California, where black alkali has done much damage, a second demonstration tract was installed. The history of this tract is briefly as follows: Part of the land was purchased in 1889 at $350 per acre, the average value of land in the vicinity at that time. In 1890, alkali began to show, and in 1898 and 1899 the land was practically abandoned. In 1903 the Bureau of Soils installed tile drainage on 20 acres. Irrigation by the basin method was begun in March and continued until July 15. At the beginning of the demonstration, 18 acres contained too much alkali for crop production. On July 15 all but two acres were sweet enough for a crop. Water gave out at this time, however, and part of the alkali in the subsoil was again raised to the surface by capillarity. The next season's work reclaimed the land from alkali sufficiently to permit crop growth.

Similar results have been attained at other points in the West, and the question of alkali, the greatest difficulty in the path of the irrigation farmer, can be said to be solved. Tile drains are not necessary, but will be found, in the end, to be cheaper than open drains. A few drains installed at the beginning of irrigation will act as preventives and will insure the land from damage by alkali. Once the rise of alkali takes place, the expense of reclamation becomes greater, and at the present time in many places it is more economical to take up new land and abandon the old.

Literature.

The following list of publications bearing on the subject of alkali soils and alkali reclamation is given for further reference: Lyman J. Briggs, Bulletin No. 16, Bureau of Soils; Field Operations, Bureau of Soils, 1899; B. C. Buffum, Bulletins Wyoming Experiment Station; Frank K. Cameron, Bulletins Nos. 17, 18, Bureau of Soils; Field Operations, Bureau of Soils, 1899; Wm. H. Heileman, Cir-

cular No. 12, Bureau of Soils; Bulletins Washington Experiment Station; E. W. Hilgard, California Station Reports and Bulletins (many numbers); Tenth Census Volume on Agriculture; Weather Bureau Bulletin No. 3, (many other papers in journals); Thos. H. Kearney, Report No. 71, Department of Agriculture (Yearbook 1902); Thos. H. Means, Bulletins and Circulars, Bureau of Soils; Field Operations, Bureau of Soils, 1899–1900; J. D. Tinsley, Bulletins New Mexico Experiment Station; Milton Whitney, Bulletin No. 14, Bureau of Soils; Farmers' Bulletin No. 88.

ALKALI SOILS IN RELATION TO PLANTS

By *T. H. Kearney*

This discussion will be confined to the relation between plant growth and alkali. The subjects to be considered in this connection are: (1) Factors controlling the action of alkali on plants. (2) The relative tolerance for alkali of the important crop plants. (3) Possibilities of increasing this tolerance. (4) The use of crops in reclaiming alkali land. (5) The value of the natural vegetation as an indicator of alkali in the soil. Some of the effects of alkali on vegetation are shown in Figs. 684–689.

Factors controlling the action of alkali on plants.

It is impossible to discuss intelligently the effect of alkali in the soil, without taking into consideration a number of controlling factors. The most important of these are: (1) The chemical composition of the alkali, i. e., the kind of salts and the proportion in which each is represented. (2) The distribution of the alkali in different depths of the soil, with which is associated: (3) The rooting habit of the plant, whether deep or shallow. (4) The texture of the soil. (5) The water content of the soil and its fluctuations during the growth of the plant. (6) Indirect action, by affecting the development of associated organisms, both beneficial and harmful. (7) The physiological constitution of the plant, which largely determines its power of resisting alkali, some species being constitutionally more tolerant than others, although nothing in their obvious structure may account for their greater resisting power. The present chapter will consider only the first six factors.

Fig. 684. Alkali spot in grain field in Utah. The hardier plants on the edges of such spots may be used in breeding for alkali resistance. (Pp. 523–4.)

The chemical composition of the alkali.—The salts which make up the bulk of the so-called "alkali" are pretty much the same the world over. They are the chlorids, sulfates, carbonates and bicarbonates, often with smaller quantities of the nitrates and phosphates of the alkalis and alkali earths, especially sodium, potassium, calcium and magnesium. Of these, sodium chlorid (common salt) and sodium sulfate (glauber salt) are usually the most abundant. In different localities, and often in the same field within distances of a few rods, great differences can be detected in the kinds and relative proportions of the salts present. On the other hand, a whole region is sometimes characterized by the predominance of some one salt or combination of salts, to such an extent that geographical names can be given to the different types of alkali.

The alkali of the soil is practically always a mixture of several salts, and for this reason the great differences in the degree of harmfulness of the various salts that manifest themselves when each salt is present alone in a water solution are usually not observed in the soil. A notable exception is sodium carbonate, which, if present in quantity, is easily recognized by its disastrous effect on vegetation. It is the so-called "black alkali," and, unlike the sulfates and chlorids that are collectively known as "white alkali," is a true alkali in the chemical sense, turning red litmus paper blue. It is most easily identified when it occurs in moist places, where by its corrosive action on organic matter it stains the surface of the soil dark brown or black, and gives to standing water the color of strong coffee. In contact with the roots and crown of a plant it corrodes the tissues and, if sufficiently concentrated, will fairly girdle the base of a tree by eating into the bark. The effect of the girdling is soon manifested in the yellowing and premature dropping of the leaves. The California Experiment Station has shown that injury to fruit trees from this cause can often be prevented by placing gypsum or land-plaster around their crowns. Because of the very violence with which "black alkali" attacks plants, their limits of tolerance for it are usually more sharply defined and more easily ascertainable than is the case with other types of alkali.

Sodium carbonate is said to be three to four times as harmful in the soil as sodium chlorid (common salt). The consensus of opinion is that an amount of carbonates equal to one-tenth of one per cent of the dry weight of the soil will prevent the germination or kill the seedlings of most of the common crop plants; and that one-twentieth of one per cent is often enough materially to injure the crop. Jensen observed fruit trees in Washington that had been killed by 0.1 per cent of alkali in the first three feet of the soil (0.15 per cent in the surface foot) when the bulk of the salts was sodium carbonate. Loughridge found orange trees in southern California slightly injured by as small a quantity as 0.025 per cent of sodium carbonate in the first three feet, where that salt formed a large part of the total alkali. The California Experiment Station has made the interesting observation that small seeds, like those of alfalfa and the meadow grasses, are more easily destroyed by black alkali than larger seeds, like Indian corn and beans.

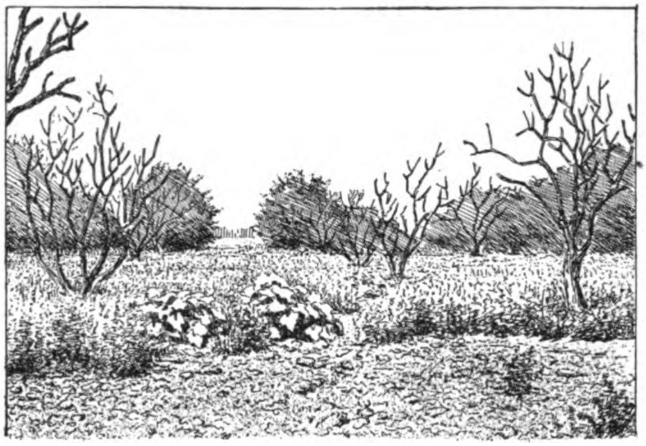


Fig. 685. Effect of alkali in apricot orchard in California.

Vertical distribution of the alkali.—To say that a given soil contains a certain percentage of alkali means nothing, unless we know how this amount is distributed in different depths at different seasons of the year and during different stages of growth. If, at the time a crop of alfalfa or barley is planted, a large part of the alkali is accumulated at or near the surface, it will be almost impossible to get a stand unless the seed is put in deep, or unless by irrigating heavily before seeding the excess of salts is washed out of the surface. If a good stand is thus secured, it will itself keep down surface accumulation by shading the ground and thus reducing evaporation from the soil. If the land is then occasionally flooded, no danger is usually to be apprehended during the life of the crop. In the case of crops like sugar-beets and garden vegetables which leave much of the soil unshaded, the return of the alkali can be prevented by frequent cultivation, which effectively cuts down the evaporation by maintaining a dry mulch on the surface.

In alkali soils the period of germination and of the first two or three weeks' growth is the critical one for most plants. This is perhaps due not so much to the young plants being constitutionally more sensitive than older ones, as to the fact that their roots have not yet had time to penetrate below the first few inches of the soil, where a large part of the alkali is often accumulated in the form of a crust.

The great importance of vertical distribution as determining the capacity of the soil for crop production is shown by the fact that a fine crop of barley was observed by Mesmer in soils containing 3 per cent of alkali (chiefly sulfates) in six feet, the bulk of the salts being found in the lower three feet; while in other places 0.2 to 0.4 per cent of alkali in six feet was enough to prevent growth, having been mostly accumulated near the surface at the time the barley was seeded.

The root habit.—After the seedling stage is passed, it depends largely on the character of the root system as to how the plant is affected by the vertical distribution of the alkali. A shallow-rooted cereal, for example, is much more likely to be injured by an accumulation of salts near the surface than is a plant like alfalfa, the roots of which soon find their way into lower depths of the soil. On the other hand, the deep-rooted crop may be injured by deposits of alkali lying below the first one or two feet that would in no wise harm a crop of wheat or barley, unless subsequently brought up by the rise of the water-table.

Fruit trees are often observed to fail suddenly in land in which they have grown vigorously for several years, either because their roots have at last reached a deep-lying layer of alkali or because a gradual rising of the water-table has brought the salts up to the roots. It is not improbable that in some cases deep-rooted plants will tolerate a greater amount of alkali if situated in strata of soil alternating with zones that are relatively free from salts, than a smaller amount more uniformly distributed, for they will be able to develop the greater part of their root system in strata containing little alkali and can thus support the injury suffered by their lateral roots where the alkali is stronger. The date palm is said to be a case in point.

The texture of the soil.—The harmfulness of a given percentage of alkali also depends largely on the soil texture. A fine-grained clay or loam not only has a much greater water capacity than a coarse sand, but, its absorptive powers being greater, much more of the salt is withdrawn from the capillary spaces. Thus, in Utah, Sanchez found that in a heavy loam sugar-beets grew well in the presence of 1.5 per cent of alkali in the first six feet, while in a soil of sandy texture they were injured by 0.65 per cent in the first foot, with successively smaller percentages of salts down to the sixth foot.

Moisture content of the soil.—The fluctuations in the moisture content of a soil are of great importance in determining the harmfulness of the alkali it contains. The salts in the soil can affect the plant, either beneficially or harmfully, only when dissolved in water. The greater the water content of a soil the more dilute will be the solution, supposing the total amount of salts present to remain constant. Thus, if the alkali amounts to 1 per cent of the dry weight of the soil, the solution will be twice as concentrated and twice as injurious to plants when the soil holds 10 per cent of moisture as when it holds 20 per cent. Hence, a crop is sometimes found to thrive in one soil and to perish in another, the percentage of alkali and the texture of the soil in each case being the same, because in the first a high moisture content has been maintained throughout the growing season while the second soil has been allowed to dry out at intervals.

Indirect action of alkali.—Various indirect effects of alkali on plants need investigation. Some of these are: the influence of alkali salts in the soil on the nitrifying organisms associated with leguminous crops, on the fungous and bacterial diseases of roots, and on insect enemies which pass some stage of their existence in the ground.

Relative tolerance of the important crop plants.

In considering the value of a crop plant for alkali soils, we must take into account not only the ability of the plant itself to grow in the presence of a certain amount of salts, but also the effect of the alkali on the quantity and quality of the product, whether seed, fruit, fiber or sugar. The California Experiment Station has stated that no decrease in the value of grapes for wine-making purposes could be detected in soils that did not contain enough alkali noticeably to injure the vines themselves. On the other hand, the same Station has found pear trees growing vigorously in soils where they could produce only poor or worthless fruit. The writer has found alfalfa plants making a fair growth where there was too much alkali for the production of good seed; cotton plants doing well where the length and quality of their fiber was decidedly inferior; and beet plants with healthy-looking tops, although the roots were much smaller and the sugar content much lower than in other parts of the same field where less alkali occurred. It is thought by many that an amount of alkali too small to be injurious is sometimes beneficial rather than neutral, e. g., by stimulating sugar production in beets and cane, improving the strength and color of cotton fiber, giving wine grapes a desirable degree of acidity, and the like.

Fig. 687. Canal in gravelly river bluff, showing seepage of alkali in the killing of vegetation.

Small field crops.—(1) Cereals.—Barley, wheat and oats are the only cereals extensively grown in alkali soils in the United States. Of these, barley is generally regarded as the most resistant; but in North Dakota, where sulfates form most of the alkali, Jensen found oats more resistant. Examining only the first foot of the soil, he found that: barley in 0.40 per cent gave a good crop, in 0.70 per cent a poor crop; wheat in 0.45 per cent gave a good crop, in 0.55 per cent was killed; oats in 0.50 per cent gave a good crop, in 0.60 per cent a fair crop, in 0.80 per cent a poor crop. A fair crop of barley can generally be obtained in soils containing 0.4 to 0.6 per cent of "white alkali," if well distributed in the first six feet. Under the same conditions, a fair stand can sometimes be obtained in 0.6 to 1 per cent of alkali. When much sodium carbonate is present, the limit is of course lower; but the California Experiment Station considers barley twice as resistant as wheat to "black alkali."

When the bulk of the alkali is sodium chlorid or sodium sulfate, 0.4 per cent of total salts in the first six feet seems to be about the limit for a good growth of wheat. The durum or macaroni wheats are considered more resistant than soft wheats. In Utah,

Fig. 686. Alkali flat produced by sub-irrigation from canals and higher irrigated lands, below St. John's canal, Phoenix, Arizona.

oats gave a fair stand when the alkali (mostly sodium chlorid, or common salt) amounted to 0.4 per cent in the first three feet of soil, while they failed in 0.7 per cent, chiefly held in the second foot. The California Experiment Station has reported rye to be about as resistant as barley, while in southern Arizona, where, however, it is little grown, it is said to be much less resistant. Indian corn is little grown in alkali soils in the United States. In Egypt it is said to fail on land that is not too salty to yield good crops of cotton and of rice.

(2) Forage crops.—(*a*) Meadow grasses.—Of the cultivated grasses, timothy appears to be the most resistant, growing well in Montana in soils containing 0.9 per cent of total salts (largely sodium sulfate) in the first six feet. Smooth brome, redtop and perennial rye-grass seem also to be rather tolerant of alkali. Some of the less valuable native meadow grasses, however, such as salt-grass and tussock-grass, are found to be exceedingly resistant. In North Dakota, where the alkali is generally of the sulfate type, good meadows of native grasses have been observed where there was 1 to 1.5 per cent of total salts in the surface foot of the soil; grass was found growing knee-high where there was over 1 per cent of salts uniformly distributed through the first three feet of soil.

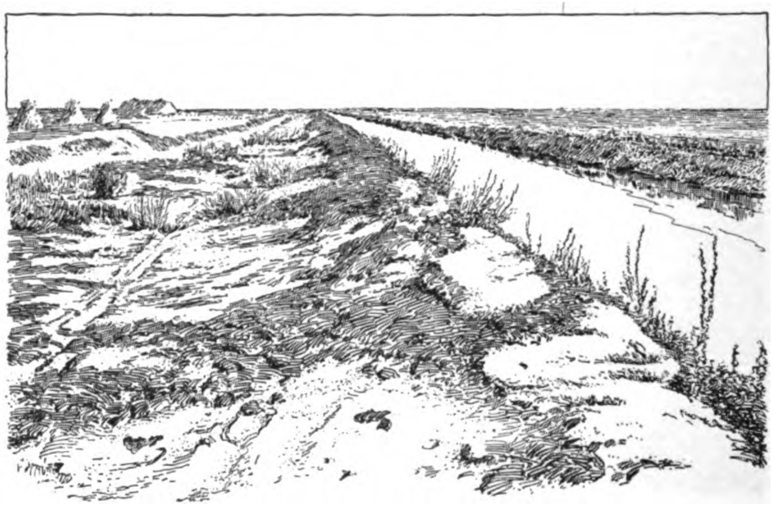


Fig. 688. Alkali appearing on ditch bank in Southern California.

(*b*) Sorghum.—In California, sorghum has been observed to grow well when the surface foot of soil contained 0.9 per cent of alkali (mostly sulfates) and when the first four feet held 0.5 per cent (about one-half carbonates, the remainder largely sulfates). When the alkali is mostly sulfates or chlorids, a fair stand can often be secured when there is 0.6 to 1 per cent in the first six feet of soil.

(*c*) Leguminous forage crops.—Most leguminous crops are sensitive to alkali. Alfalfa, the only plant of this class that is extensively grown in regions where alkali soils occur, appears to be one of the most resistant, but probably this is largely due to the fact that its roots soon penetrate below the layers of soil where most of the alkali has accumulated. Of other leguminous plants tested by the California Experiment Station, hairy vetch (*Vicia villosa*) was found to be the most tolerant of "white alkali," giving a fair stand where there was nearly 0.5 per cent in the first four feet; but bur-clover (*Medicago maculata*) was the most resistant to black alkali. Opinions differ as to the ability of sweet clover (*Melilotus alba*) to endure much alkali; but in Utah it is said to grow well even when the total salts (chiefly sodium chlorid) amount to 1 per cent in the first five feet.

A stand of alfalfa can often be obtained in soil containing a very large total amount in lower depths, if the few inches of the surface soil are practically free from alkali at the time of seeding, but if the distribution is fairly uniform, 0.4 per cent of "white alkali" in the upper six feet of soil appears to be generally about the limit for a successful seeding. Alfalfa, especially in the first stages of growth, is peculiarly sensitive to "black alkali."

As much as 0.7 per cent of total salts (chiefly sulfates) in the first four feet of soil may not injure well-established alfalfa; but when the moisture content fluctuates greatly during the growing season, even less than 0.6 per cent can seriously injure old stands.

(3) Sugar crops.—Sugar-beets are probably more tolerant of alkali than any other widely grown crop plant of the United States. They can germinate and pass the seedling stage in the presence of 1 per cent of "white alkali." They will almost always make a good growth when there is 0.6 per cent of alkali in the first six feet (if chiefly chlorids or sulfates), and frequently when there is 1 per cent. Beets seem also to be more tolerant of "black alkali" than most other crops. Even if a good stand can be obtained, it is probably not advisable, as a rule, to grow beets when the soil contains more than 0.6 to 1 per cent in the first six feet; for when greater amounts of salts are present the roots are small, their keeping quality (when siloed for seed production) is poor and their sugar content and purity are much impaired.

(4) Textile crops.—In western Texas, where upland varieties are grown, cotton is said to be the most alkali-resistant crop of the region. Both in Egypt and in Arizona, a fair quality of fiber is

produced by Egyptian varieties in the presence of 1 per cent of total salts (mostly sodium chlorid) in the first two or three feet of the soil. Flax in North Dakota was observed by Jensen to suffer most where the alkali was accumulated in the surface foot. The presence of 0.8 per cent in the first foot killed the plants.

(5) Garden vegetables.—Asparagus seems to be easily first among garden vegetables in its tolerance of alkali. In California, Means and Holmes have found that it grows well in 0.6 per cent of total salts (if mostly sulfates or chlorids) in the first five feet of the soil. However, it is said to be sensitive to "black alkali." Beets and onions are said to grow well where the first five feet of the soil contain 0.4 to 0.6 per cent of total salts. Potato plants are apparently very resistant and will grow where the surface foot of the soil contains nearly 0.5 per cent of "white alkali," although the tubers produced are watery and do not keep well. Globe artichokes are among the most tolerant of garden vegetables. Some of the more sensitive vegetables are beans (all kinds), peas, celery, and, with a few possible exceptions, the cucurbits (squashes, cucumbers, melons, and the like).

(6) Tobacco.—Tobacco is not to be recommended for growing in alkali land, as its combustibility is impaired by the salts.

Trees and vines—(1) Grapes.—According to the California Experiment Station the greatest amount of total salts in the first three feet of soil in which grape-vines were found to show no sign of injury was 0.3 per cent, of which one-fifth was carbonates (black alkali). When the total alkali was 0.5 to 0.6 per cent in the upper three feet and carbonates formed one-half of it, the vines were killed. Raisin grapes, in which the highest possible sugar content is desired, should not be grown in alkali soils.

(2) Orchard crops.—It is exceedingly difficult to determine the alkali resistance of trees. The vertical distribution of the salts cannot be overlooked, because of the great differences in the root systems of different species. The thickness of the bark of the crown largely determines the amount of injury to be apprehended from "black alkali." Most fruit trees are easily injured by standing water, and as the water-table is usually high in alkali soils it is often hard to decide whether it is the water or the alkali that is doing the harm. So far as present data go, the order of tolerance of the orchard crops is about as follows, beginning with the most tolerant: date-palm, pomegranate, pear, quince, olive, fig, apple, almond, peach, plum, orange and lemon. It seems reasonably certain that further investigations will not change this order so far as the first two are concerned. There

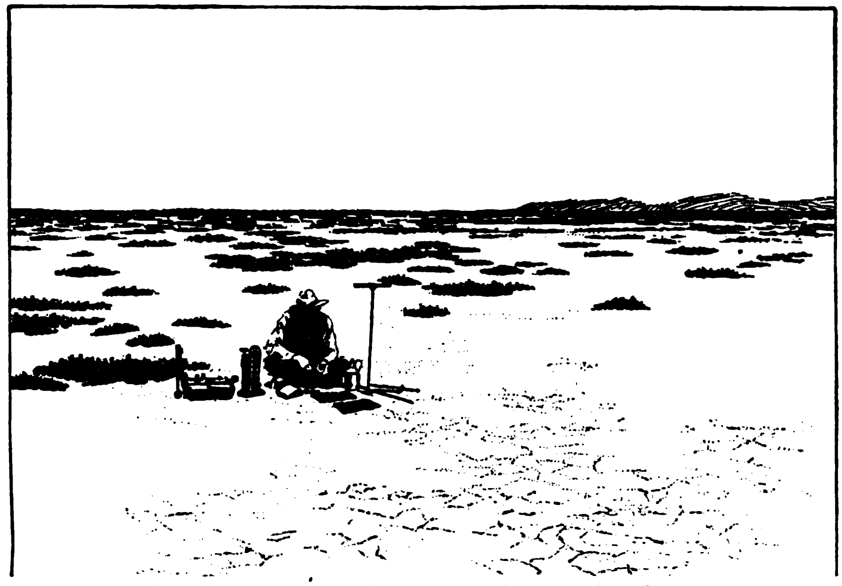


Fig. 689. Alkali land showing growth of pickle-weed in California.

is some doubt as to the relative degree of resistance of the next four, although it is pretty certain that all of them are more tolerant of alkali than are the prunaceous stone fruits and the citrous fruits. It is uncertain which of the latter two groups is really the more resistant, but there is no doubt that oranges and lemons are extremely sensitive. The English walnut also has a great aversion to alkali.

Increasing the tolerance of crop plants for alkali.

Two methods suggest themselves for increasing the alkali resistance of crop plants. One is the introduction from other countries of strains or races that have become adapted to alkali soils during the centuries they have been grown on them. Much has already been accomplished along this line by the United States Department of Agriculture, which has imported various durum or macaroni wheats, strains of alfalfa from central Asia and northern Africa, and numerous varieties of the date-palm.

The second method for increasing alkali resistance is by breeding, i. e., by selection practiced with that end definitely in view. Near the margin of the bare spots that often occur where a crop is growing in alkali soil, we often find scattered plants that are barely able to survive and to mature seed. (Fig. 684.) Examination of soil around such plants generally shows them to be exposed to more alkali than average individuals of the species or variety can endure. Many examples could be given. While 0.6 per cent of total salts is often the limit of tolerance for barley, a few plants have been observed to head out in the presence of nearly 1 per cent (mostly chlorids) in each of the first three feet of the soil. Sugar-beets rarely give a good stand where there is more than 1 per cent of alkali; yet occasional beets of fair size, having a sugar content of 12 per cent, have been found where the first two feet of the soil contained 2 per cent. Well-established stands of alfalfa are often injured by 0.5 to 0.6 per cent of "white alkali," yet resistant plants can ripen seed when the first two feet of the soil hold 1.5 per cent or even 2 per cent. By saving seed from such plants for a number of generations, it is thought that alkali-resistant strains of the more important crop plants can be secured. Deterioration in other respects must, however, be guarded against. The short-lived field crops naturally lend themselves more readily to breeding work of this kind than orchard trees, grape-vines and the like; although opportunities for selecting resistant individuals among the latter are by no means lacking.

Crops used in reclaiming alkali land.

In Egypt, where large areas of salt lands have been reclaimed successfully by drainage and flooding, a number of crops are grown during the process. The most important are rice, samar (a reed used for making mats), barnyard grass (*Panicum Crus-galli*), and berseem (Egyptian clover), the last two being forage plants. A crop that can endure large quantities of water, and that can therefore be grown on alkali land during the course of reclamation by flooding, should be of great advantage to western agriculture, since it would be so much gained if the land were producing something while it is being washed. Berseem, being a winter crop, would seem especially desirable for this purpose in the warmer parts of the West, where flooding can be advantageously practiced at that season, irrigation water being then less needed for other purposes and evaporation being less intense than in summer.

The crops at present most grown in the United States on alkali land that is being reclaimed are barley and, especially in the southwestern states and territories, sorghums (including kafir corn). It is recommended that, for this purpose, the sorghum be seeded at the bottom of furrows and the crop be given as many heavy irrigations during the season as the abundance of the water-supply will allow. By then breaking down the ridges and flooding as often as possible during the winter and growing another crop of sorghum the second summer, land can often be reclaimed in two years. It is probable that in combination with winter flooding of the bare land, the growing of sugar-beets will also prove effective in reclamation, since beets are resistant, and, being a cultivated crop, evaporation can be kept down by preserving a dry mulch on the surface of the soil.

The natural vegetation as an indication of alkali.

It is well known that different kinds of alkali weeds grow in soils containing different strengths of alkali. Some of them are found only where there is too much alkali for the successful culture of most crop plants. The samphires, or pickle-weeds (species of Salicornia, Fig. 689), and the bushy samphire, or Kern greasewood (*Allenrolfea occidentalis*), appear almost always to indicate that there is 1 per cent or more of total salts in the first few feet of the soil. But the majority of alkali weeds have a very wide range of adaptability, growing in soils that are practically free from alkali as well as in soils that contain so much as to be unfit for any crop. Such are the saltworts (species of Suæda) and the well-known salt-grass (*Distichlis spicata*). Moreover, some plants are so averse to alkali that their absence in a piece of land, otherwise adapted to them by the texture and moisture content of the soil, is the safest of all indications that it contains a dangerous amount of alkali. Such "negative indicators" are the "black sage" (*Artemisia tridentata*) in the Great Basin region and the creosote bush in the regions near the Mexican boundary.

In considering the value of plants as indicators, it must be remembered that no species is everywhere associated with a fixed percentage of alkali. The different kinds of salts and the proportions in which they occur, their distribution in different depths of the soil, the moisture content and its fluctuations, the texture of the soil and, finally, the climatic conditions are all expressed by the character of the natural vegetation. But, as has been seen, the cultivated crop is no less an expression of the combined influence of these factors. It follows that the native growth of the soil will be the best guide to its agricultural possibilities, when the presence or absence of certain types of natural vegetation shall have been correlated with the possibility of growing successfully each of the important crop plants.

Literature.

Much information in regard to alkali soils and the tolerance of different crop plants for alkali will be found in the following publications: Alkali studies, by B. C. Buffum and E. E. Slosson, Ninth and Tenth Annual Reports Wyoming Agricultural Experiment Station, and Bulletins Nos. 29 and 39, Wyoming Experiment Station; Investigations on the native vegetation of alkali lands, by J. B. Davy and R. H. Loughridge, Report California Agricultural Experiment Station for 1895-97, p. 53; The variability of wheat varieties in resistance to toxic salts, by L. L. Harter, Bulletin No. 79, Bureau of Plant Industry, United States Department of Agriculture (1905); Some mutual relations between alkali soils and vegetation, by T. H. Kearney and F. K. Cameron, Report No. 71, United States Department of Agriculture (1902); Crops used in the reclamation of alkali lands in Egypt, by T. H. Kearney and T. H. Means, Yearbook United States Department of Agriculture for 1902, p. 573; Agricultural explorations in Algeria, by T. H. Kearney and T. H. Means, Bulletin No. 80, Bureau of Plant Industry, United States Department of Agriculture, 1905; Alkali and alkali soils, by W. H. Heileman, Bulletin No. 49, Washington Agricultural Experiment Station; Origin, value and reclamation of alkali lands, by E. W. Hilgard, Yearbook United States Department of Agriculture for 1895, p. 103; Nature, value and utilization of alkali lands, by E. W. Hilgard, Bulletin No. 128, California Agricultural Experiment Station (1900); Annual Reports of the California Experiment Station for 1879, 1880, 1888-89, 1890, 1891-92, 1897-98; The distribution of the salts in alkali soils, by E. W. Hilgard and R. H. Loughridge, Bulletin No. 108, California Agricultural Experiment Station (1895), and Annual Report same station for 1894-95, p. 37; Investigations of alkali lands, by R. H. Loughridge, Report of California Agricultural Experiment Station for 1895-97, p. 37; Effect of alkali on citrus trees, by R. H. Loughridge, Report of the Director, California Agricultural Experiment Station, for 1897-8, p. 99; Tolerance of alkali by various cultures, by R. H. Loughridge, Bulletin No. 133, California Agricultural Experiment Station (1901); Reclamation of alkali lands in Egypt, by Thos. H. Means, Bulletin No. 21, Bureau of Soils, United States Department of Agriculture (1903); Division and Bureau of Soils, United States Department of Agriculture, Reports of Field Operations for 1899, 1900, 1901, 1902 and 1903; Effect of alkali on seed germination, by John Stewart, Ninth Annual Report Utah Agricultural Experiment Station, p. 26 (1898); Alkali, by J. D. Tinsley, Bulletin No. 42, New Mexico Agricultural Experiment Station (1902); The alkali soils of Montana, by F. W. Traphagen, Bulletin 18, 54, Montana Agricultural Experiment Station (1904). Reclamation of alkali soils, by C. W. Dorsey, Bulletin No. 34, Bureau of Soils. Bulletin No. 35, Bureau of Soils, by Dorsey, discusses alkali resistence of plants and gives a bibliography of American writings.

TREATMENT OF "ALKALI SPOTS"

By *T. Lyttleton Lyon*

The preceding articles treat the subject of alkali soil mostly from the viewpoint of the arid regions, where such soil occurs in large and more or less continuous areas; but one of the characteristics of the soil of the semi-arid regions is the occasional occurrence of small "alkali spots." (Fig. 684, page 519.) They may vary in size from a few square yards to several acres. The handling of this soil is not so difficult as that of the larger and more strongly impregnated tracts, found in irrigated regions. The alkali is usually white, being composed largely of sulfates of magnesium, sodium, potassium and calcium, chlorids of sodium and potassium, and some nitrates. These alkalis or soluble salts usually do not occur in sufficient quantities to prevent completely the growth of crops in times of good rainfall, but in periods of drought the concentration of the salts, and the compact condition of the soil which they help to produce, give rise to conditions so unfavorable to the crop that it is very likely to succumb, either because of the alkali alone, or because of the combined effect of alkali and drought. The effect of the salts is to make the soil more compact, and thus to dry more readily.

Alkali spots may occur either on hillsides or on bottom-land. They are more common on heavy soil than on light. Land that has alkali spots is likely to be good, aside from that objection, and when the effect of the alkali has been sufficiently mitigated the land is usually very productive.

There are a number of operations that may be applied with profit to these soils. Deep plowing is always desirable, but it should never be done when the soil is very wet. One of the simplest and most effective methods of treatment is plowing under fresh barnyard manure or other coarse and easily decomposable organic matter. This lessens the compactness, produces humus and promotes drainage. In a dry season it is possible that the fresh manure will dry the soil, as decomposition will be slow, but it is not advisable to delay treatment of alkali spots from fear of any such result. The manure should be added in heavy dressings and the applications continued for a number of seasons.

As thorough drainage as possible should be secured by means either of tile drains or open ditches. Tile drains involve a considerable initial expense, and are likely to drain the water slowly at first, but they are a permanent cure for the difficulty, and improve greatly the mechanical condition of the soil. Open drains are not so effective as tile drains, but they are of service, and should be used in connection with the other methods of treatment. The alkalis are soluble and are readily carried off by water if it can be brought in contact with them.

Certain plants are more tolerant of alkali than are others, and they absorb large quantities of salts which are removed from the soil when the crop is harvested. Sugar-beets are for these reasons one of the best crops for alkali land, and can be raised on most alkali spots. Alfalfa and brome-grass will be of service on such soils; of the cereals, oats is a good crop to raise.

Constant cropping will improve the alkali spots, regardless of what the crop is. Moisture should evaporate through plants, not directly from the soil. Thorough stirring of the surface soil should be given hoed crops, and to the entire spot when no crops are on the land. Fall plowing is desirable, unless the soil drifts, because alkali soil has a tendency to compact and thus aërate inadequately. By plowing in the fall a better opportunity is given the soil to weather. Plowing for corn and surface planting is generally better practice than listing.

By the use of the methods mentioned, especially when combined, any alkali spot as commonly found in semi-arid regions may be rendered very productive in a few years.

CHAPTER XVI

SOIL SURVEYS AND THEIR SIGNIFICANCE

By MILTON WHITNEY and J. A. BONSTEEL

THE early explorers and colonizers of the present domain of the United States were, almost without exception, in search of materials that would yield immediate financial returns to the companies of "gentlemen adventurers" by whom the expeditions were outfitted. Thus the early accounts of the new continent are taken up with relations, largely fabulous, of the precious minerals, furs and naval stores from which the associations and the governments at home might reap rich profits.

With the coming of real colonization enterprises, information regarding the soil, the climate, and the natural vegetable products of the country, was eagerly desired, and many of the earlier explorers used their knowledge of the new continent for the enlightenment of their countrymen. Some of the accounts were written more with an idea of pleasing the reader than with a view of strict adherence to fact.

Aside from the very general accounts of this period, which lasted until the end of the eighteenth century, nothing was written and little was known of the exact character of the soils of the new continent. About the close of the Revolutionary War, an agricultural revival was inaugurated in England, and the work of Sir Humphrey Davy, coupled with the interest of great landowners, brought agriculture prominently to the front as a subject for investigation. An echo of this English movement soon followed in the newly established States, and agricultural societies began to be formed. They devoted themselves first to making known the resources of their respective localities, to reforming the demoralized systems of cultivation of the time, and to publishing special papers on various technical subjects. The New York State Agricultural Society in 1798 and 1799 employed Dr. Mitchill to study the soils of that state, and his reports may be found in the Medical Repository, Vols. I, III and V. Dr. Mitchill first established beyond doubt the vegetable and organic origin of peat and muck deposits. Such material had previously been classed as one of the "earths," i. e., of unknown, probably inorganic, origin.

Other societies, notably in Rhode Island, Vermont and Pennsylvania, made scattered observations on the soils of their localities. In 1821, Featherstonehaugh wrote an extremely able and scientific paper for the New York State Board of Agriculture, in which he developed the germ of the soil survey idea in the following words:

"These soils also are various in their appearance and properties, and the forms of vegetables and their properties appear to depend on the particular nature of the soil they grow in, aided in some degree by climate and situation. We know that in sandy districts the pine tree universally prevails; we may therefore conclude that the pine is the natural production of that soil. We know also that the particular varieties of trees and plants, such as black ash and the spruce, are invariably found in swamps and low, marshy places; we therefore very justly conclude they are the natural productions of a rich vegetable mold continually saturated with water. It being then conceded that particular soils under the same circumstances will always produce the same results, the next step to learn is, how many varieties of soil there are and what are the properties of each variety, as they are connected with vegetation." (Featherstonehaugh, Memoirs of the Board of Agriculture of New York State, Vol. I, 1821, p. 54, et seq.)

This attitude of mind in regard to soils was greatly affected by Liebig's work on the chemical analysis of the mineral matter of soils. Liebig's work seemed to reduce soil study and agriculture to a system of mathematical accuracy and certainty. It was believed, and the belief has not entirely passed away, that an analysis of any given plant would show its requirements from the soil; that an analysis of the soil would show its capabilities or deficiencies; that these being known, the material necessary to supply any soil deficiencies might be applied in the form of natural or artificial chemicals, and the process of producing crops would be made easy.

The simplicity of such a proceeding rendered the Liebig hypothesis wonderfully popular, and the sweep of its popularity naturally obliterated the development of the physical, climatic and drainage studies of the soils. Thousands of chemical analyses were made, and as early as 1820 to 1830 various agricultural surveys were organized in Maine, Massachusetts, New York and North Carolina. One of the first official recognitions of the importance of soil study was in the establishment in 1847 by the legislature of Maryland of the official position of Agricultural Chemist for the state. The chemist was required to spend one year in each of the districts of the state and one month in each county, and he was also required to visit each election district for the purpose of studying soils and other agricultural conditions. His duties included the analyses of specimens of soils sent to his office, and of all the different varieties of soils which he himself might find within the state.

In the year 1850, Dr. D. D. Owens, assisted by Dr. Robert Peters, began an extensive chemical examination of the soils of Kentucky, in connection with the Geological Survey of that state. About 1858, Dr. E. W. Hilgard began the study of the geology and the soils of Mississippi. He classified the soils of the state according to their geological origin, their physical and chemical characteristics, and the character of their natural vegetation. His report on the agriculture and geology of Mississippi was published in 1860. In it is to be found the first soil map published in the United States. The map covers one octavo page, and represents the generalized soil conditions of the entire state of Mississippi. The Civil War interrupted this work by Dr. Hilgard, and the scene of his activities was transferred to California in 1875. In 1880, he prepared a generalized soil map of the cotton-producing states, and also special maps of each of these states, for publication in connection with his report on cotton, included in the Tenth Census. In this work he employed the same basis of geological origin, chemical and physical properties, and the character of the natural timber growth for the classification of soils. The report is accompanied by a large number of chemical analyses.

In 1861, and at other more recent dates, Johnson pointed out the doubtful utility of the ordinary chemical analysis of soils, as an indication of the relation of the soil to plant growth, except in special and rather rare cases. He showed that the ordinary amounts of fertilizer can not be detected in the soil by the usual methods of chemical analysis, and also that nearly all the analyses by the methods then used indicated an amount of plant-food even in the poorest soils sufficient for the production of many average crops.

In 1891, the Maryland Experiment Station made an investigation of the physical properties of Maryland soils in coöperation with the United States Department of Agriculture. This work was published in 1892 as a Weather Bureau bulletin entitled, "The Physical Properties of Soils in their Relation to Crop Production." In this bulletin it was shown that there was a direct relationship existing between the texture of the soils, the crops to which they were adapted, and the agricultural methods best suited to the land. This had already been recognized to a certain extent by the farmers themselves in the specialization of truck-farming on the light, sandy soils of the coastal plain. This investigation showed further that nearly all soil types that differ in agricultural value and in adaptation to crops, differ also in texture and in their other physical properties, to an extent sufficient to account for the differences in crop adaptation as observed in the field. In 1893, a generalized map of the state of Maryland was prepared for distribution at the Columbian Exposition. On this map were shown the relationships of the soils to the geology of the state; the relationships of the soils to actual crop production; and the distribution of both soils and dominant crops throughout the state. This map, although published on a small scale, contained all of the fundamental principles on which the more detailed mapping of the Bureau of Soils of the United States Department of Agriculture has since been based.

In 1899, the Division of Soils of the United States Department of Agriculture began actual field mapping of the soils of the United States. The soils of the New England tobacco district along the Connecticut river were mapped, and the adaptation of the different kinds of soils to the different varieties of tobacco was pointed out. At the same time, maps were made of various areas located in the arid West and Southwest, and an additional study of alkali and irrigation conditions undertaken. This work has been continued to the present time, and the Bureau of Soils now maintains about twenty parties continually in the field for the mapping of the soils of the United States.

Soil-mapping.

The field classification of soils is based on those features which control the kind of crop that should be raised on the different kinds of soils. The fundamental principle of the classification involves the water-holding capacity of the soil, its surface topography and its climatic surroundings. The features causing variation in these respects are found to be the texture of the soil, or the absolute size of the soil grains; the structure of the soil, or the state of aggregation of the soil grains; the amount, condition and distribution of partially decayed organic matter within the soil; the altitude, surface topography and the character of the materials underlying the soil, i. e., the physiography of the soil body.

In making a soil map of any given region, it is first necessary to secure an accurate base map on which the conditions actually found may be plotted. For this purpose, the United States topographic sheets on the scale of one inch to the mile are considered as standard. In areas for which such maps have not been made, the best available county maps, or maps made by private parties, are secured, and their scale changed when necessary, by photographic process, to the standard of one inch to one mile. If the map is imperfect either because of age or because it represents only a few of the necessary features to be considered, it is revised by the field party, who use a plane-table for plotting on the map any additional features that may be required.

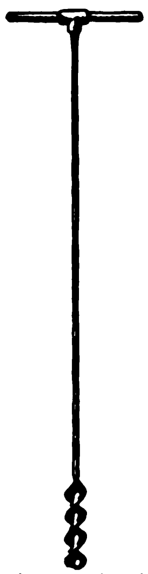


Fig. 690. The soil auger used by field parties of the Bureau of Soils, for securing samples.

Each field party is equipped with an ordinary one and one-half-inch auger having a three-foot stem (Fig. 690); by means of this auger a sample of the surface soil is bored out, and its texture, structure and other characteristics are determined by the operator. The boring is continued to a depth of three feet, and the record of the boring taken in the note-book. When several of these borings distributed over a field have been taken, the field man is in a position to classify the soils that he has examined into their respective groups, as clay, sandy loam, gravelly loam, and so on. He then proceeds to plot the extent and the boundaries of these various types of soil on his map, using colored pencils to indicate the different types. Two men work together in the party. As they proceed along the road one is engaged in making borings while the other is recording distances, sketching boundaries, or doing any necessary plane-table work. Under ordinary circumstances the party can

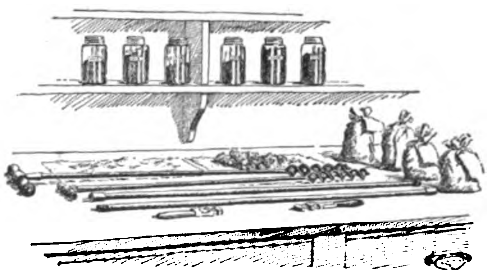


Fig. 691. Outfit for sampling, shipping and storing soil samples.

take a sufficient number of borings each day to enable them to map four to six square miles of territory. Unusual complexity of soil conditions reduces this rate, as unusual uniformity increases it. When a sufficient amount of territory has been covered to warrant general conclusions, a study of the crop conditions on each soil is conducted simultaneously with the field mapping. The farmers of the region are interviewed with regard to the agricultural methods employed, the crops raised on each soil type and the yields secured; on the use of fertilizers, both regarding amount and kinds, and the results secured on the various soil types for the different crops. Any special industry, such as trucking, fruit-growing, berry-raising or sugar-beet production, is thoroughly studied. The transportation facilities and the markets to which

Fig. 692. Electrical instrument for determination of amount of alkali in a soil.

produce is shipped are ascertained. The history of the agricultural development of the region is secured, either from pioneer settlers or from local histories, and these are supplemented by more general information furnished from the central office. The local climatic conditions are learned, and these, in connection with the records of the United States Weather Bureau, furnish the material for a report on the climate of the district being surveyed.

On the completion of the field work within any given area, the completed field map is sent to the office to be prepared for engraving and for publication. Submitted with the map is a report on the different soil types, their origin, properties and crop adaptation; the agricultural history and development of the given region; the transportation facilities, the markets and existing condition of agriculture; and the climate and the physiography of the region. These constitute the map and report published on each area by the Bureau of Soils.

Special problems in soil-mapping.

Under arid conditions it becomes necessary, in addition to the usual work, to study water-supply and irrigation problems. It is also necessary in many of the arid region areas to make a special study of the occurrences of excessive amounts of soluble salts, commonly known as "alkali." For this purpose, each party is supplied with an electrical instrument (Fig. 692) by means of which a sample of soil can be tested rapidly and the percentage of soluble salt present in it can be determined. By the use of this machine, the percentage of alkali present in each foot of soil from the surface to a depth of six feet or more is ascertained.

The party also carries apparatus for the determination of the character of the alkali salts, since the dreaded "black alkali" (sodium carbonate) is fatal to plant growth when present in small quantities, while various other salts known as "white alkali" may be tolerated by plants when present even in considerable amounts. Thus, not only the amount but the kind of alkali is determined in the field, and a special alkali map is prepared on which is shown the amount and kind of alkali present to a depth of six feet or more. (Fig. 693.)

As the alkali conditions are frequently controlled by the depth from the surface of the soil to the point of saturation, a ground-water map is also constructed. This shows the depth at which the soil contains stagnant water.

Soil provinces and types.

The work of the soil survey since 1899 has developed the fact that the United States may be divided into soil provinces. In each of these provinces the soils are formed by similar geological processes from materials of similar character. Thus, in the coastal plain province the soils are sediments, eroded from older rocks, transported, sorted and deposited as marine or river deposits. In the piedmont province, however, the soils are directly formed through the weathering of underlying rocks, chiefly crystallines. Thus these two provinces are units, with material distinctions between all of their respective soils.

Within each province are groups of soils known as series. These groups are essentially similar in all characteristics except texture, but a complete series grades continuously from coarse gravelly and sandy soil types to fine-grained silt or clay types. Each series is given a geographical name to express its province location and its uniformity of characteristics aside from texture. It is divided into individuals or types by the addition of a texture name or class name. A single example will illustrate the classification.

Province	Coastal Plain.
Series	Norfolk.
Class	Sand.
Type	Norfolk sand.

The type name thus signifies that the material named is a loose, incoherent sand of gray to yellow color, occurring along the Atlantic or Gulf coast, formed as a marine sediment.

In this nomenclature the method of all scientific naming is followed, and the geographical name corresponds to the genus as the class or texture name does to the species. The series name is usually adopted from a locality where the series relationship of the soils is first recognized. The texture name is descriptive of the individual. [For further information on soil provinces, series and types, see Soil Survey Field Book of 1906, Bureau of Soils.]

The practical value of the soil survey.

The reports and maps published regarding single areas are chiefly valuable within the areas concerned, but the collections of maps and reports on areas scattered over nearly every state and territory within the country form the basis for many important generalizations in regard to the relationships existing between crops and soils, and between crops and climate. Again, the study of a single area may show that within this area some desirable crop is being produced with special success on a given kind of soil, and that its production is not particularly successful on other kinds of soil. The map of such an area has fully as high a value in other sections of the United States as within the area itself, since, wherever the given type is found under the same climatic conditions, the experiences on the first area may be taken as conclusive proof that the same crop may be raised to advantage. Similarly, when experiments have been conducted concerning crop varieties, cultural methods, fertilization, systems of rotation, forced production and various forms of intensive farming, on any given soil type, the results of these experiments may or may not be applicable at a distance from the point where the experiment was conducted. However, if a soil map of the experiment plot has

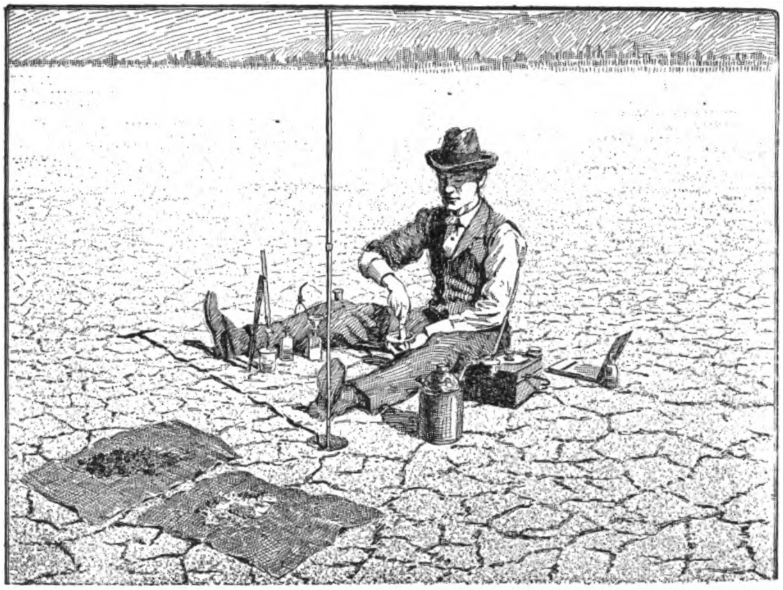


Fig. 693. Making an alkali determination in the field.

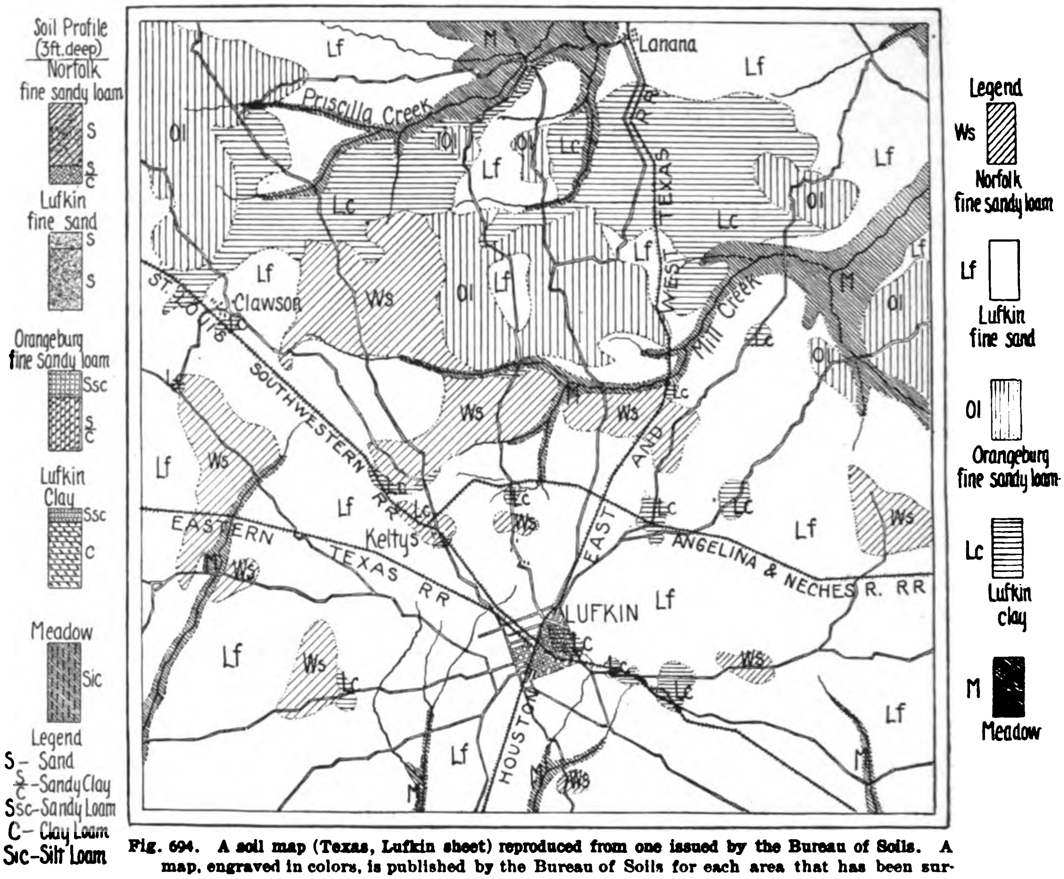


Fig. 694. A soil map (Texas, Lufkin sheet) reproduced from one issued by the Bureau of Soils. A map, engraved in colors, is published by the Bureau of Soils for each area that has been surveyed by its field parties.

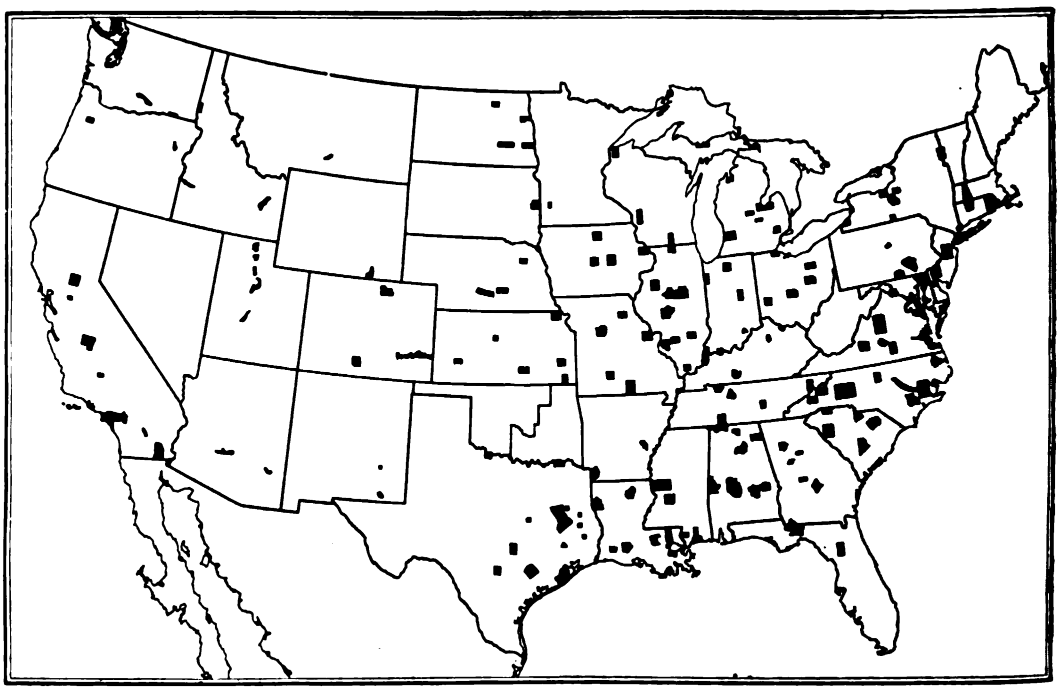


Fig. 695. Black spots show the areas surveyed by the Bureau of Soils, United States Department of Agriculture, to July 1, 1905.

been made, and a report on the surrounding conditions has been rendered, the results of the experiment become applicable wherever other maps and reports show that the same conditions exist. In other words, the results of experiments are made of general application instead of being confined to small, local, and rather indefinite areas.

The extent of the soil survey work.

The extent of the soil survey work in the United States is best shown by the tables that follow. It should be held in mind that this work has been completed between May, 1899, and June 30, 1905:

regions immediately at the doors of the great cities.

Literature.

The following list includes the most important publications on soil survey work and allied subjects, some of them of historical value. The majority of the earlier references are to works in which the relationship of soils to geology or the chemical properties of soils are discussed. Natural History of New York, Vol. I, Part V, 1846, by E. Emmons; Report on the Geological and Agricultural Resources of New Jersey, 1857, by George H. Cook; Report of the State Chemist, Maryland, by Higgins and Tyson, 1847-1859; Soils of Maryland, by Whitney, Bulletin 21, Maryland Experiment Station; Resources of Maryland, Report of World's Fair Commission, Chapter on Soils, by Whitney, 1893; Correlation of Soils and Geology of Maryland, by Williams and Whitney, 1893; Geology of Tennessee, by Safford; Geology of Kentucky, by Owens and Peters; Geology of Alabama, Parts I and II, by E. A. Smith; Agriculture and Geology of Mississippi, by E. W. Hilgard, 1860; Report on Cotton Production in some of the Southern States, by E. W. Hilgard, Tenth Census, Vol. VI; Culture and Curing of Tobacco, by Killebrew, Tenth Census; Soils of Tennessee, by Dabney, Vol. X, No. 3, Tennessee Agricultural Experiment Station; Soil Investigations in the United States, by Whitney, Yearbook, United States Department of Agriculture, 1899; Field Operations of the Bureau of Soils, 1899, 1900, 1901, 1902, 1903, 1904; consult monthly List of Publications of the United States Department of Agriculture.

AREAS SURVEYED BY THE BUREAU OF SOILS OF THE UNITED STATES DEPARTMENT OF AGRICULTURE TO JUNE 30, 1905.

State or territory	Square miles	Acres	State or territory	Square miles	Acres
Alabama	6,863	4,392,320	Brought forward	53,886	34,487,040
Arizona	611	391,040	Nebraska	1,561	999,040
Arkansas	877	561,280	New Jersey	1,303	833,920
California	6,335	4,054,400	New Mexico	129	82,560
Colorado	2,350	1,504,000	New York	3,280	2,099,200
Connecticut	518	331,520	North Carolina	6,618	4,235,520
Delaware	314	200,960	North Dakota	1,825	1,168,000
Florida	1,708	1,093,120	Ohio	3,055	1,955,200
Georgia	1,813	1,160,320	Oregon	446	285,440
Idaho	1,135	726,400	Pennsylvania	1,978	1,265,920
Illinois	5,925	3,792,000	Porto Rico	330	211,200
Indiana	2,036	1,303,040	Rhode Island	1,085	694,400
Iowa	2,303	1,473,920	South Carolina	4,002	2,561,280
Kansas	2,345	1,500,800	South Dakota	485	310,400
Kentucky	1,370	876,800	Tennessee	3,046	1,949,440
Louisiana	3,568	2,283,520	Texas	7,479	4,786,560
Maryland	2,663	1,704,320	Utah	1,501	960,640
Massachusetts	796	509,440	Vermont	227	145,280
Michigan	3,078	1,969,920	Virginia	4,338	2,776,320
Minnesota	486	311,040	Washington	680	435,200
Mississippi	2,902	1,857,280	West Virginia	254	162,560
Missouri	3,783	2,421,120	Wisconsin	1,591	1,018,240
Montana	107	68,480	Wyoming	309	197,760
Carried forward	53,886	34,487,040		99,408	63,621,120

States . . . . 42 Territories 3

If the soil survey work in the United States has demonstrated one thing more markedly than all others, it is the immensely varied soil and climatic resources of the country. Less than a score of staple crops now comprise the total agricultural export resources of the country. Four hundred different types of soil are already known. They lie under conditions of temperature varying from semi-tropical to sub-arctic; under conditions of rainfall marked at one extreme by eight feet of precipitation per annum, and at the other by less than two inches; under conditions of surface topography which range from the level prairies of the central states to the mountain coves and valleys of the Alleghanies and the high plains and sierras of the West; under conditions of settlement, such that certain areas show less than one person occupying one square mile of territory, while other regions show more than one person per acre; under conditions of transportation that vary from the 3,000-mile haul between coast and coast to the 10-mile haul in the market-garden or trucking

PART IV

THE ATMOSPHERE ENVIRONMENT

Agriculture rests on the production of plants; and the production of plants is conditioned on the environment in which they grow. This environment is comprised of the soil and the atmosphere.

The soil environment we are in the habit of discussing. The atmosphere environment is given little rational thought: it is accepted. It is true that we cannot change or modify atmospheric conditions to any great degree; but these conditions dominate all life on the globe. It is our part not only to understand them but to adapt ourselves to them. A good part of the farming of the world is not yet adapted to its climate: this defect is far more important and significant than our lack of knowledge of mere weather or than the necessity of foretelling atmospheric changes. To adapt itself to climate is the greatest problem of agriculture.

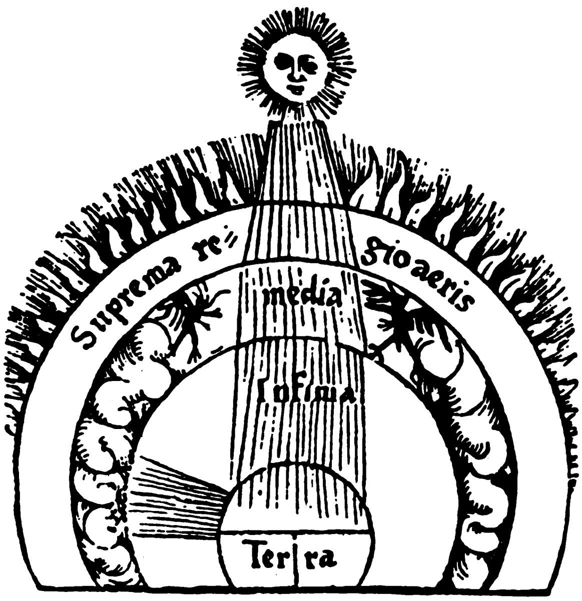


Fig. 696. A mediæval conception of the earth's atmosphere. Among the clouds of mid-air are the devils who reign supreme in that sphere. From Eck's "Aristotelis Meteorologica," published at Augsburg, in 1519.

This problem of adaptation to weather and climate is not peculiar to agriculture. One of the overmastering necessities of mankind is to accept the unmodifiable environment in which it is placed and to make it a means of personal development. Few persons are in harmony with the weather environment. Setting themselves against it, they consume energy that might be utilized in constructive work, and put themselves in such a mental attitude that full satisfaction of life is impossible.

Sympathy with the weather develops weather wisdom. Such wisdom is found with farmers, sailors and naturalists, the accuracy and value of it depending on the degree of harmony with the environment. We are not consciously educating our people toward sympathy with weather, notwithstanding that we live in a time of great effort to interest them in plants and animals. The natural history of weather changes is as important to know as the life histories of birds and trees. The first interest of the child in the out-of-doors world is in the air, the sky and the weather. We seem to be losing something of the desire for personal weather wisdom because of the great development of instrumental means of measuring atmospheric changes and the perfecting of governmental weather service. We are leaving weather-knowledge to the weather man. Nothing is now more needed in nature-teaching than to direct the attention to winds and storms and calms and frosts. The farmer, of all men, should know his meteorology; and this accounts for the length and the detail of this Part IV on which we are entering.

The farmer should be able to judge the weather by the local signs. These signs or indications are the expressions of normal and natural atmospheric conditions. Careful and continued observation should enable one to connect the appearances with their causes, or at least with the results that are likely to follow, and therefore give a man a rational basis for predicting many common changes.

There is also such a thing as studying climate, and some of the larger aspects of weather, in terms of animals and plants. Observations on the migration of birds, the opening of leaves, the ripening of fruits, the hibernating of animals, and other life-epochs, can be so made and collated as to constitute an almost perfect expression of the seasonal changes. This subject is known as phenology (contraction of phenomenology). It is the science of the periodicity of organisms as related to environment, particularly to climate. It has been carefully studied on the continent of Europe by Hoffmann, Linsser, Ihne and others; and physiological constants, measuring the seasons, have been worked out. Thermometers, barometers, and other instruments, measure only certain attributes or expressions of weather; and even when the results are all put together, they cannot make as perfect a measure of climate as do the epochs of the animals and plants, for these respond to all the weather elements. Some of the subjects involved as touching agriculture are indicated in Chapter XVII of Bailey's "Survival of the Unlike"; and instructions for taking phenological observations, by the same author, are given in the Monthly Weather Review, for September, 1896.

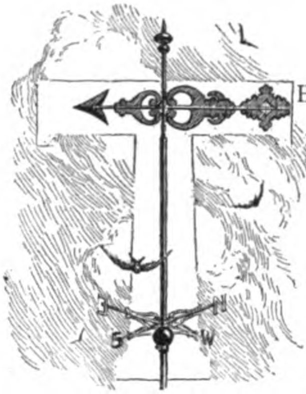
The history of the gradual rise of a science of weather constitutes one of the most interesting chapters in the evolution of the race. For centuries storms were attributed to the wrath of deity or the machinations of devils. The atmosphere, as well as the destinies of men, was thought to be controlled by superior agents and by the planets and the moon. These were centuries of credulity, when a habit of reasoning from natural cause to effect had not developed or was suppressed by authority. We have not even yet outgrown this credulity and mental confusion, for persons still believe in the occult influence of the moon, books are written describing the influence of the signs of the zodiac as if they were realities, and weather-quacks have large followings; and the old dread, fear and awe of storms, as if they were supernatural agencies, still linger with us. Gradually there arose a conviction that atmospheric phenomena are natural rather than supernatural, and that they are not necessarily beyond the knowledge of man. This rising intelligence early took the form of foreknowledge or prognostication. The first great experimental contribution to a science of meteorology was Franklin's experiment with the kite in 1752. This experiment aroused wide-spread discussion. Efforts were made to apply the quickened knowledge to agriculture. It was only twenty years thereafter that John Mills published in London a book called "An Essay on the Weather; with remarks on the Shepherd of Banbury's rules for judging of its changes; and directions for preserving lives and buildings from the fatal effects of lightning. Intended chiefly for the use of Husbandmen." The book contains a most interesting appendix consisting of an "abstract of the meteorological observations made by the Œconomical Society of Berne, for the year 1766." These observations are of the phenological kind, rather than measurements. There are general notes on winds, frosts, crops, diseases, and agricultural practices. This little book is scientific in its method; its chapters explain how to prognosticate weather from vegetables and animals; sun, moon and stars; clouds; mist; rain; winds; changes of the seasons. The subject is approached from the viewpoint of nature-knowledge, an attitude that we need still to emphasize.

All men of trained intelligence now approach the subject of weather rationally, in the same spirit that they study any other natural phenomena, assuming that it is governed by law. There are a number of recent popular American books on weather that may be recommended, following the excellent early "Treatise on Meteorology," by Professor Loomis in 1868. Loomis' book has a good bibliography up to that date. Omitting the subject of climate, the following writings may be mentioned: William Blasius, "Storms," Porter & Coates, 1875; Ralph Abercromby, "Weather," International Scientific Series, Appleton, 1887; A. W. Greely, "American Weather," Dodd, Mead & Co., 1888; William Ferrel, "Popular Treatise on the Winds," John Wiley and Sons, 1889; W. M. Davis, "Elementary Meteorology," Ginn & Co., 1894; Thomas Russel, "Meteorology; Weather, and Methods of Forecasting," Macmillan, 1895; Frank Waldo, "Modern Meteorology," Scribners, 1893; Waldo, "Elementary Meteorology," American Book Co., 1896; R. DeC. Ward, "Practical Exercises in Elementary Meteorology," Boston, Ginn & Co., 1899; A. L. Rotch, of the Blue Hill (Mass.) Observatory, Boston, "Sounding the Ocean of Air," London, 1900; J. Hann, "Handbook of Climatology," New York, The Macmillan Co., 1903 (translated by R. DeC. Ward). If the reader wishes to know what mental and physiological effects the weather produces, he should consult Edwin Grant Dexter's "Weather Influences," Macmillan, 1904. For popular signs, consult Edward B. Garriott, "Weather Folk-Lore and Local Weather Signs," Weather Bureau Bulletin No. 33, United States Department of Agriculture, 1903. A set of weather signs, and a table for computing frost predictions, are contained in Chapter XVIII of the "Horticulturist's Rule-Book." Those desiring to inquire into the history of meteorology should consult the chapter, "From 'The Prince of the Power of the Air' to Meteorology," in Andrew Dickson White's "History of the Warfare of Science." For charts, see Bartholomew's Atlas of Meteorology (Vol. 3 of his Physical Atlas), London.

CHAPTER XVII

WEATHER SERVICE AND WEATHER KNOWLEDGE

By WILFORD M. WILSON



THE ORGANIZATION OF WEATHER SERVICES contemplates a three-fold function: (1) The collection and tabulation of meteorological facts by means of observations; (2) the correlation of these facts and the solution of the problems they present; (3) the application of the knowledge thus secured to the public needs. They are equally important and are interdependent. The present article is concerned chiefly with the last-mentioned function; but in discussing the practical utility of weather services it must not be overlooked that the application of the principles of meteorology to the every-day needs of the farmer, the mariner, the shipper, the manufacturer and the seeker after health or pleasure, has been made possible only through the painstaking labor of those devotees to pure science who gathered the facts and formulated the theories, working methodically and patiently day after day.

Weather services are best known, perhaps, through the medium of their forecasts, and the public estimate of their efficiency is determined largely by the success in this effort. Absolute success, however, has not been attained, nor will it be attained until a perfect understanding of the complex problems presented by the atmosphere has been reached. But so much has been accomplished in the past fifty years that he is indeed lacking in faith who will say that this twentieth century may not witness the perfect solution.

The purpose of this article is to explain briefly the practical workings of the weather service of this and other countries, and to point out wherein their work may be utilized in agricultural practice. The work of such service is of necessity of a generalized character, and its value to the farmer depends largely on his ability to localize and adapt it to his own needs. It may not be substituted for a knowledge of the conditions in his own locality, which every farmer should possess; but the farmer should rather supplement that knowledge with the larger and more extended view to be secured through the weather service.

No attempt is made to discuss the underlying principles of meteorology further than to point out the significance of some of the more common weather signs. Such a discussion is given by Cleveland Abbe, Jr., in his article in Chapter XVIII.

Weather forecasting based on observations.

The methods employed by all meteorological services in the world for forecasting the weather are practically the same, and depend, first, on the fact that disturbances or storms within the earth's atmosphere move over the surface of the earth along well-defined tracks or paths at a fairly uniform speed, and, second, that the electric telegraph has made it possible to herald the approach of these disturbances far in advance of their appearance. Without this means of instantaneous communication, weather services as now organized could not exist, for the weather forecaster must have before him not only the weather conditions as shown by his own instruments, but a broad view of the weather over a large territory—the larger the better. The United States Weather Bureau, which is the most highly organized and favorably situated weather service in the world, has at present about 200 regular stations where observations are recorded twice each day and telegraphed to about 100 offices where maps and bulletins are prepared, including the Central Office at Washington, D. C. These observing stations were originally located with regard to the telegraphic facilities that existed, and also with a view to securing reports from points distributed over the country as evenly as possible. The service was organized in 1870, with about 50 stations. Since telegraphic facilities have become so wide-spread, and the value of the weather servic has been demonstrated, stations have been located more and more with reference to their value to the public as centers for the distribution of meteorological information. In addition to the above stations, daily telegraphic reports are received, through the courtesy of the

Plate XXIII. Fruit-growing in Nova Scotia. Hillcrest Orchard, Kentville

governments, from Canada on the north, Mexico and the West Indies on the south, the Azores and western Europe on the east, thus covering practically all of the inhabited parts of the northern half of the western hemisphere.

Each observatory is manned by one or more trained observers and is equipped with mercurial barometers, thermometers, wind-vanes, rain- and snow-gages and anemometers, and many have sunshine recorders, barographs, thermographs, and other devices which register automatically the local weather conditions and changes. Exactly at 8 A.M. and at 8 P.M. each day of the year, 75th meridian or eastern time (this is the standard of time used throughout this article), an observation of the weather conditions where the observatory is located is made and placed on the wires. This observation consists of a reading of the barometer, which shows the weight or pressure of the atmosphere at that place; the temperature of the air at the time of taking the observation; the highest and lowest temperatures during the previous 12 and 24 hours; the condition of the weather, whether clear, cloudy, raining or snowing; the direction and force or velocity of the wind; the rain or snow; and the kind, direction and movement of the clouds. To this is added, as occasion may require, special information as to rapid changes in the conditions, thunder-storms, frosts, and the like.

All this information is reduced to about five or six words by the use of a very ingenious cipher code. The cipher code is used not for secrecy but for the sake of economy, and is translatable at sight.

How weather observations are gathered.

Exactly at 8 o'clock in the morning and evening, certain telegraph wires are given up exclusively for the transmission of weather observations. These wires are arranged in "circuits." For example, one circuit may start at St. Paul, Minnesota, and, passing through a number of weather stations, end at the Central Office at Washington. At each of these offices is an operator seated at his instrument ready to copy the reports from other stations, or to send his own. The main circuit is tapped at convenient points by wires or circuits from either side, so that when the work begins the messages flow toward the main circuit much as streams converge toward the main channel of a river. Each operator has a particular time for placing his own report on the circuit, and he copies all reports from other stations passing over the wire. At the terminal points of the main and auxiliary circuits, reports from stations in adjacent territory are gathered and placed on the wire, so that at the end of an hour not only the Central Office at Washington but a hundred or more local offices are in possession of observations taken an hour before over a large territory.

Construction of the weather map.

As soon as the reports come from the wires, they are passed to the observers and the preparation of the daily weather map begins. For this, an outline map of the United States is used, the location of each station being shown on the map by a circle. Opposite each circle is entered the temperature, the barometric pressure, the velocity of the wind, and the precipitation. The direction of the wind is indicated by an arrow passing through the circle and pointing in the direction in which the wind is blowing. The condition of the weather is shown by shading the circle for cloudy, half-shading it for partly cloudy, and leaving it open for clear weather; if it be raining or snowing at the time of observation, it is indicated by the appropriate letter, R or S, placed in the circle.

When the observations are all entered, heavy lines called isobars (Fig. 697) are drawn through points having the same atmospheric pressure, a line being drawn for each one-tenth of an inch in the height

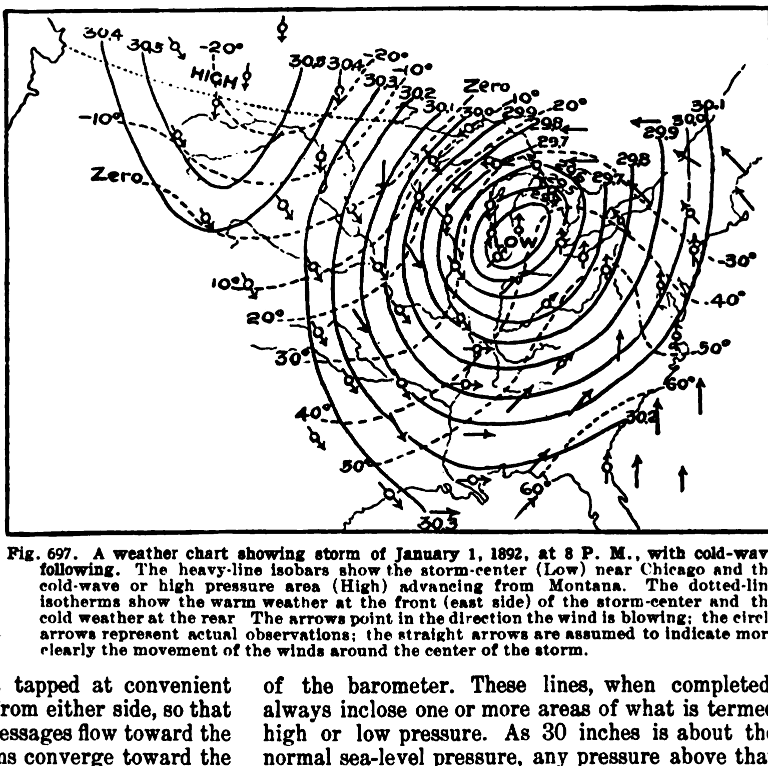


Fig. 697. A weather chart showing storm of January 1, 1892, at 8 P. M., with cold-wave following. The heavy-line isobars show the storm-center (Low) near Chicago and the cold-wave or high pressure area (High) advancing from Montana. The dotted-line isotherms show the warm weather at the front (east side) of the storm-center and the cold weather at the rear The arrows point in the direction the wind is blowing; the circle arrows represent actual observations; the straight arrows are assumed to indicate more clearly the movement of the winds around the center of the storm.

of the barometer. These lines, when completed, always inclose one or more areas of what is termed high or low pressure. As 30 inches is about the normal sea-level pressure, any pressure above that point may be considered high, and any pressure below may be considered low. The highest point or center of the high pressure area is marked "high," and the lowest point or center of the low pressure area is marked "low."

Dotted lines, called isotherms, are also drawn through points that have the same atmospheric temperature, a line being drawn for each ten degrees of temperature. Heavy dotted lines are sometimes used to inclose areas where decided changes in temperature have occurred during the preceding 24 hours. Shaded areas are used on the maps issued at Washington, and at several stations, to show areas within which precipitation in the form of rain or snow has occurred during the preceding 24 hours. In the printed maps issued to the public the barometer and temperature data, from which the lines are drawn, are usually omitted, and tabular matter added, giving details of maximum and minimum temperature, 24-hour temperature changes, wind velocities, and amount of precipation during the preceding 24 hours. The text printed on the map presents the forecasts for the state and station, and summarizes general and special meteorological features that are shown by the lines, symbols and tabulated data; and it points out the effect that these conditions are expected to have on the weather in the vicinity of the station during the succeeding 36 or 48 hours.

How to read the weather map.

The general movement of "lows" and "highs" in the United States is from west to east, and in their progression they are similar to a series of atmospheric waves, the crests of which are designated by the "highs" and the troughs by the "lows." These alternating "highs" and "lows" have an average easterly movement of about 600 to 700 miles a day. The "lows" usually move in an easterly, or north of east, direction, and the "highs" in an easterly, or south of east, direction.

In advance of a "low" the winds are southerly or easterly, and therefore are usually warmer. When the "low" passes east of a place, the wind shifts to westerly or northwesterly, with lower temperature. The eastward advance of "lows" is almost invariably preceded and attended by precipitation in the form of rain or snow, and their passage is usually followed by clearing weather. The temperature on a given parallel west of a "low" may be reasonably looked for on the same parallel to the east when the "low" has passed; and when the night is clear and there is but little wind, frost is likely to occur along and north of the isotherm of 40°. A "low" is generally followed by a "high," which in turn is followed by another "low."

By bearing in mind the usual movement of "lows" and "highs" and the general conditions referred to that attend them, coming weather changes may be frequently foreseen. "Lows" often move south of east from the Rocky mountains to the Mississippi valley and then change direction to north of east. "Lows" of tropical or subtropical origin often move in a westerly direction to the South Atlantic and Gulf coasts and then recurve northeastward. Cold-waves are always accompanied by "highs" and forerun them.

When isobars run nearly east and west, no decided changes in temperature are likely to occur. When isotherms directly west of a place incline from northwest to southeast, the temperature will rise; when from northeast to southwest, the temperature will fall. An absence of decided and energetic "lows" and "highs" indicates a continuance of existing weather until later maps show a change, that usually appears in the west.

The storms of the United States follow, year after year, a series of tracks, not capricious, but related to each other by very well-defined laws. The chart (Fig. 698) shows the general result of a study of storm tracks in the United States. The positions of these storm tracks have been very carefully determined. The chart indicates that, in general, two sets of tracks run westerly and easterly, one set over the northwestern boundary, the lake region, and the St. Lawrence valley; the other set over the middle Rocky mountain districts and the Gulf states. Each of these is double, with one set for "highs" and one for "lows." Furthermore, there are lines crossing from one main track to another, showing how storms pass from one to the other. The transverse broken lines show the average daily movement. The heavy lines all belong to the tracks of the "highs," and the lighter lines to the "lows." The paths are determined by the laws of the general circulation of the atmosphere and the configuration of the North American continent.

Forecasts, and methods of distribution.

For many years all official forecasts emanated from the Central Office at Washington, but with the rapid growth of the service it was found that this work could be accomplished more economically and satisfactorily by dividing the country into forecast districts. The districts are named for the city in which the central station for the district is ocated, and are as follows:

Boston district: Maine, New Hampshire, Vermont, Rhode Island, Massachusetts and Connecticut.

Chicago district: Illinois, Indiana, Michigan, Wisconsin, Minnesota, Iowa, Missouri, Kansas, Nebraska, South Dakota, North Dakota, Montana.

Denver district: Colorado, New Mexico, Arizona, Utah, Wyoming.

Louisville district: Kentucky, Tennessee.

New Orleans district: Louisiana, Texas, Oklahoma, Indian Territory, Arkansas, and advisory warnings for Mexico.

San Francisco district: California, Nevada.

Portland (Oregon) district: Washington, Oregon, Idaho.

New York City district: New York City.

Washington district: New York, except New York City, Pennsylvania, New Jersey, Delaware, Maryland, District of Columbia, Virginia, North Carolina, South Carolina, Georgia, Florida, Alabama, Mississippi, Ohio, West Virginia.

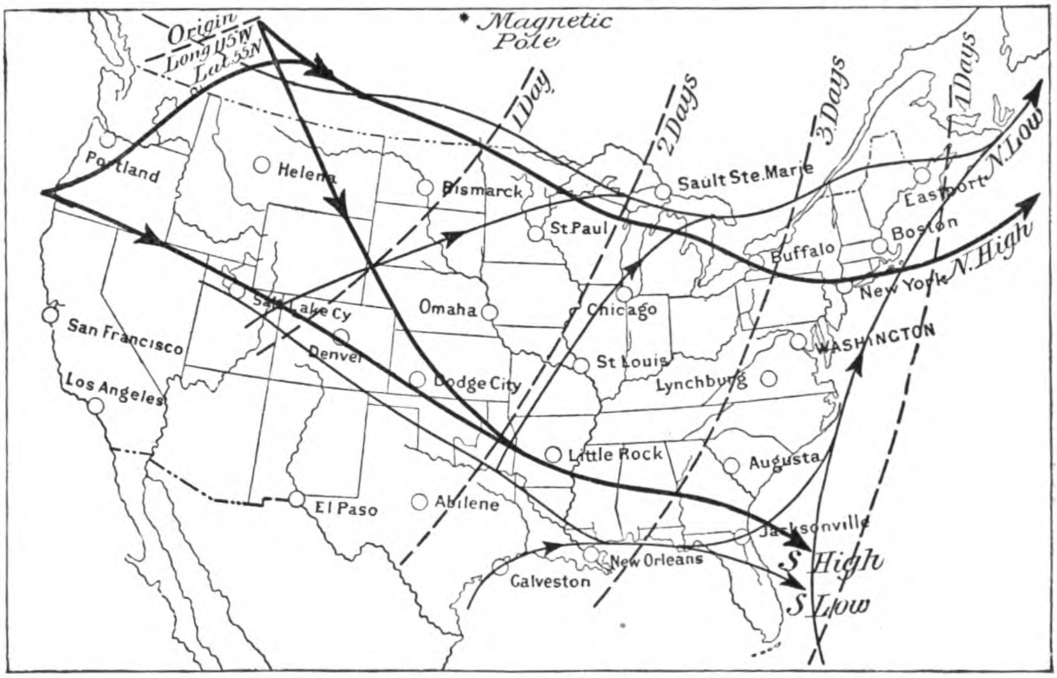


Fig. 698. Mean tracks and average daily movements of storms in the United States.

The official in charge of each forecast district issues the morning forecasts, cold-wave, frost and storm warnings for his district, emergency and hurricane warnings being reserved for the Central Office at Washington. The forecast official at Washington issues all night forecasts and warnings except those for the San Francisco and Portland districts, where the night forecasts and warnings are issued by the officials in charge for the respective districts.

The forecasts made from the 8 A. M. observations cover a period of 36 hours, ending at 8 P. M. of the following day. The night forecasts cover a period of 48 hours. In the morning forecasts no mention is made of the weather expected between 8 A. M. and 8 P. M. of the day of issue except when the morning observations show that the conditions as outlined in the forecast issued 24 hours before have changed materially. The 12-hour period following 8 P. M. of the day of issue is designated as "night," and the following 12-hour period by the day of the week; e. g., "Partly cloudy tonight; Thursday, rain and warmer." When the temperature is not mentioned no decided change is anticipated.

Within two hours after the morning observations have been taken, the forecasts are telegraphed from the forecast centers to more than 2,000 principal distributing points, where they are further disseminated by telegraph, telephone and mail. In this way the forecasts reach more than 200,000 addresses daily, the greater part being delivered early in the day and none later, as a rule, than 6 P. M. of the day of issue. This system of distribution is wholly under the supervision and at the expense of the government, and is in addition to and distinct from that effected through the press associations and daily newspapers.

Signals.—At many points weather flags are displayed, which give the forecasts a still wider dissemination. (Fig. 699.) At other points where the proper facilities exist, whistles are sounded at a particular hour, the length and number of the blasts indicating the weather expected as stated in the forecast. The whistle signals are as follows: A warning blast of fifteen to twenty seconds' duration is sounded, to attract attention. After this warning the longer blasts (four to six seconds) refer to weather, and the shorter blasts (one to three seconds) refer to temperature; those for weather are sounded first.

Blasts	Indicate
One long	Fair weather.
Two long	Rain or snow.
Three long	Local rain or snow.
One short	Lower temperature.
Two short	Higher temperature.
Three short	Cold-wave.

Rural free delivery service.—One of the most effective methods of disseminating the weather forecasts is by means of the rural free delivery service of the Postoffice Department. The following method is usually employed:

The forecasts are telegraphed each morning, and the cold-wave, frost and other warnings as occasion may require, to postmasters from whose offices one or more rural free delivery routes radiate. Each postmaster is supplied with a set of rubber logotypes that includes all the words used by the official forecaster in expressing his opinion of the weather conditions to be expected in the particular locality during the following 36 hours. As soon as the forecast is received, the proper words are quickly selected and arranged in the form of a stamp and the necessary number of copies of the forecast prepared on cards furnished for the purpose. Each carrier takes sufficient cards to supply the patrons on his route, and thus the forecasts

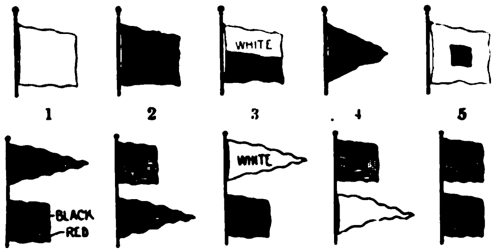


Fig. 699. Weather signals. Upper row, general weather flags: No. 1, alone, indicates fair weather, stationary temperature; No. 2, alone, indicates rain or snow, stationary temperature; No. 3, alone, indicates local rain or snow, stationary temperature; No. 1, with No. 4 above it, indicates fair weather, warmer; No. 1, with No. 4 below it, indicates fair weather, colder; No. 2, with No. 4 above it, indicates rain or snow, warmer; No. 2, with No. 4 below it, indicates rain or snow, colder; No. 3, with No. 4 above it, indicates local rain or snow, warmer; No. 3, with No. 4 below it, local rain or snow, colder; No. 5, cold-wave.

Lower row, storm and hurricane warnings (red and white flags with black centers). *Storm warning.*—A red flag with a black center indicates that a storm of marked violence is expected. The pennants displayed with the flags indicate the direction of the wind; red, easterly (from northeast to south); white, westerly (from southwest to north). The pennant above the flag indicates that the wind is expected to blow from the northerly quadrants; below, from the southerly quadrants. By night a red light indicates easterly winds, and a white light above a red light, westerly winds.

Hurricane warning.—Two red flags with black centers, displayed one above the other, indicate the expected approach of a tropical hurricane, or one of those extremely severe and dangerous storms which occasionally move across the lakes and northern Atlantic coast. No night hurricane warnings are displayed.

sent out from the centers at 9.30 A. M. reach many remote farming communities within a few hours. The chief difficulty in extending this service to all rural free delivery offices lies in the fact that in many cases the carriers leave on their routes in the early morning hours, before it is possible to reach the postmaster with the forecasts.

Distribution by telephone.—The rural telephone lines, which have made such phenomenal growth in the past few years, offer excellent facilities for the distribution of the weather forecasts, especially among the farmers. On June 30, 1905, 464,738 persons in the United States were receiving the weather forecasts each morning through the co-operation of the various telephone companies. The forecasts are telegraphed at government expense to local exchanges that will distribute the information to their subscribers, preference being given to those reaching farming communities. By this means the forecasts will reach the farmer at an earlier hour than when the mail is employed, and are consequently of greater value. The distribution by telephone is the most satisfactory and economical method at present employed.

Storm warnings.—In addition to the regular daily forecasts, special forecasts designed to protect certain classes of industries are made and distributed as occasion may require. Of these, warnings of storms and hurricanes, for the benefit of marine interests, are probably the most important and most valuable. Storm warnings are displayed at nearly 300 points along the Atlantic, Pacific and Gulf coasts and the shores of the great lakes, including every port and harbor of importance; and so nearly perfect has this service become that scarcely a storm of marked danger to maritime interests has occurred for years for which ample warnings have not been issued twelve to twenty-four hours in advance. The reports from the West Indies are especially valuable in this connection, as they enable the Bureau to forecast with great accuracy the approach of destructive hurricanes which, during the period from July to October, are likely to sweep the Gulf and Atlantic coasts. The sailings of the immense number of vessels engaged in ocean and lake traffic are largely determined by these warnings. Warnings displayed for a single hurricane are known to have detained in port, on our Atlantic coast, vessels valued, with their cargoes, at over $30,000,000.

Cold-wave warnings.—The warnings of those sudden and destructive temperature changes known as cold-waves are probably of next importance. These warnings, which are issued twenty-four to thirty-six hours in advance, are disseminated throughout the threatened regions by means of flags displayed at regular Weather Bureau and sub-display stations, by telegraph, telephone and mail service, to all places receiving the daily forecasts, and to a large number of special addresses in addition. The beneficial results of these warnings are manifold. Precautions are taken for the safeguarding of personal comfort and health, and the protection from freezing of produce of all

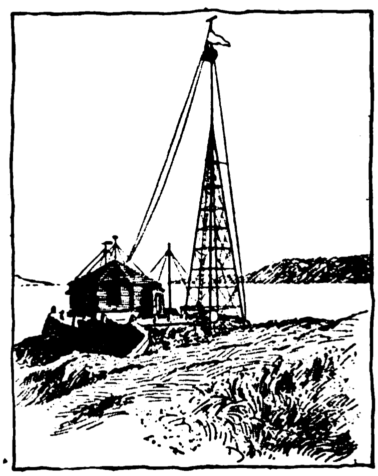


Fig. 700. United States Weather Bureau Station and storm-warning tower. Point Lobos, Cal.

kinds, steam- and water-pipes, hothouse plants and flowers. Railroads regulate the size and movement of their freight trains, ice men prepare for harvesting, and many plans for business or pleasure are made on the expectation of the conditions forecast. The warnings issued in January, 1896, for a single cold-wave of exceptional severity and extent, resulted in the saving of over $3,500,000 in the protection of property from injury or destruction.

Frost warnings.— The warnings of frost and freezing weather are also of immense value, particularly to the fruit, sugar, tobacco, cranberry and market-gardening interests. The early truck-raising industry, so extensively practiced in the regions bordering the Gulf and South Atlantic coasts, and in Florida, and which has increased so greatly in the last few years, is largely dependent for its success on the coöperation of the Weather Bureau. The growers of oranges and other fruits in Florida and California have invested large sums in tents, screens, heating, smudging and irrigating apparatus for the protection of their groves and orchards, which they put into use when notified by the Bureau of the expected occurrence of injuriously low temperatures. The value of the orange bloom, vegetation, vegetables and strawberries protected and saved on a single night in February, 1901, in a limited district in Florida, through the instrumentality of warnings of freezing weather sent out by the Bureau, was reported at over $100,000.

River and flood warnings.—The commerce of our rivers is greatly aided, and lives and property in regions subject to overflow are protected, by the publication of the river stages and the issue of river and flood forecasts based on reports received from about 300 special river and rainfall stations. On the occasion of the flood of 1897 in the lower Mississippi valley, live-stock and other movable property to the estimated value of about $15,000,000, was removed from the inundated regions prior to the flood, as a result of the warnings by the Bureau a week in advance of its occurrence.

The value of this service was emphasized in a still more remarkable degree during the great floods in the Mississippi watershed, from March to June, inclusive, of the year 1903. The flood in the upper Mississippi watershed was the greatest in its history, with the exception of that of 1844, while in many parts of the lower watershed the stages were the highest ever known. Notwithstanding the enormous volumes of water, the forecasts and warnings were most specifically accurate, both as to location, stage and date. Warnings were issued four days to three weeks in advance, and in no single instance did the forecasted stage differ from that actually recorded by more than four-tenths of a foot. The average difference was about two-tenths of a foot. The value of the property saved by the Weather Bureau warnings was beyond accurate computation, but probably exceeded that of the property saved during the flood of 1897.

Climatological service and publications.

Although the 200 regular observing stations, each representing about 22,000 square miles of territory, furnish sufficient data on which to base the various forecasts, observations at many intermediate points are necessary before the climatology of the United States can be studied properly. This need has given rise to the establishment of an important and interesting feature of the Weather Bureau in its Climatological Service. The Climatological Service is divided into forty-five local sections, each section, as a rule, covering a single state, and having for its center a regular observing station. These centers collect temperature and rainfall observations from more than 3,000 coöperative stations, and publish these data in the form of monthly reports, which are given widespread distribution. During the growing season (April to September, inclusive) each section also receives weekly mail reports from numerous correspondents, these reports being published in the form of weekly bulletins.

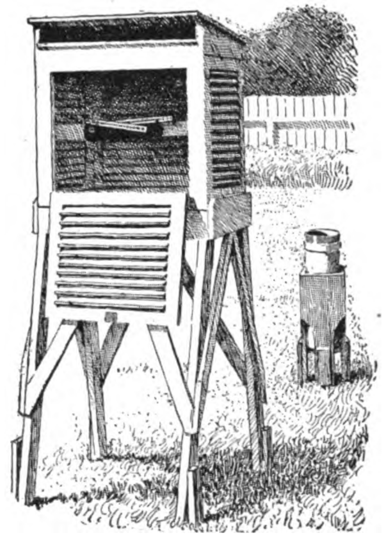


Fig. 701. Thermometer shelter and rain-gage, such as are supplied to co-operative observers.

During the same season the Central Office at Washington issues weekly a National Weather Bulletin, containing a series of charts graphically illustrating current and normal conditions of temperature and rainfall for the entire country, and a general summary of the weather, together with a brief report of the weather conditions in each state.

There is also issued at the Central Office every Tuesday during the winter a publication entitled "Snow and Ice Bulletin," which shows the area covered by snow, the depth of snow and the thickness of ice in rivers, lakes and the like, as indicated by a large number of observations made on the afternoon of the day preceding the issue of the bulletin. The publication is of special value to those interested in the winter-wheat crop, to ice dealers, and to the manufacturers of rubber goods and other articles, the sale of which is largely affected by the presence or absence of snow and ice. Throughout the cotton-, corn-, wheat-, sugar- and rice-producing sections, designated centers receive telegraphic reports of rainfall and daily extremes of temperature for publication, each local center receiving the reports from all others.

By the help of several thousand coöperative observers, many of whom have maintained local records for long periods, the Weather Bureau endeavors to collect local data and thus perfect the records that are needed for the study of the relation between climate and agriculture, forestry and other industries. The results of these observations appear in detail in monthly and annual reports published at the respective section centers, and in the Monthly Weather Review.

Other uses of the Weather Bureau.

In the raisin districts of California the forecasts are of great value. The raisin crop while drying is extremely susceptible to injury from rain, and the warnings enable the producers to protect the fruit by stacking and covering the trays. Shippers of perishable produce and goods liable to injury by heat or cold are guided largely by the weather reports in making shipments and in directing their movements while on the road. Constructors of waterworks, bridges, culverts and sewers consult the rainfall records to ascertain the maximum waterflow they will have to allow for. Architects of iron and steel structures and tall buildings consult the records of maximum and minimum temperatures and wind velocity, in order to estimate the contraction and expansion their buildings must be prepared to withstand. The records of the Bureau are of frequent use as evidence in courts of law, for which purpose they have been decided competent by the Supreme Court of the United States.

In the utilization of these meteorological data, the Weather Bureau employs a staff of officials of high scientific ability, who are engaged not only in the practical work already mentioned, but are also occupied in the elaboration of those fundamental principles which must necessarily play an important part in the development of meteorology and kindred sciences. From time to time the results of these investigations are presented to the public through the columns of the Monthly Weather Review or separately in pamphlets. The numerous offices of the Bureau throughout the country are always open during business hours, and the public are invited to visit them and avail themselves of the information contained in the records there on file.

The formation of frost and methods of protection.

"The atmosphere always contains more or less moisture in an invisible form. When at a considerable elevation above the earth this moisture, or aqueous vapor, is condensed, clouds are formed; when the process of condensation is more active and the temperature of the air is above freezing, rain falls; and when the temperature of the air is below freezing, snow is produced. When the moisture of the air in immediate contact with the earth is condensed at temperatures above freezing, dew is formed; when at temperatures below freezing, frost is deposited. Frost is, therefore, the moisture of the air condensed at freezing temperatures upon plants and other objects near the surface of the earth." (Garriott.) There are two principal processes by which plants lose this heat, viz., convection and radiation. Convection is operative only when the temperature of the whole mass of air surrounding the plant is lower than that of the plant itself, and is effective in producing frost principally on the approach of a cold-wave in which the air has a temperature of 32° Fahr. or lower. This process is of lesser importance, for the reason that the immense volume of cold air brought down from the higher elevations by the action of an anti-cyclonic condition or cold-wave is so vast that it would not seem possible to devise any adequate means for the protection of vegetation outside of hothouses under such conditions. It is fortunate, therefore, that damaging frosts rarely result from this cause, for the reason that this condition occurs principally in the early spring before vegetation is sufficiently advanced to be liable to great injury, and in the late fall when the crops are mostly matured.

The chief method by which plants lose their heat on those clear, calm nights when frost is most likely to occur, is by radiation. By radiation is meant that peculiar process by which heat escapes from an object in direct lines in the same way that rays are emitted from a source of light. Heat emitted from an object does not appreciably warm the air through which it passes, but becomes manifest only when the passage of the heat ray is obstructed by some object. A simple experiment will illustrate this fact: If a thermometer is carefully observed during a cool evening when a few clouds are occasionally passing, the temperature will be seen to fall steadily as the evening advances, possibly at the rate of 2° or 3° per hour. If, however, the action of the instrument is closely observed during the passage of a cloud, it will be seen that the fall in temperature is first checked and then a rise of 2°, 3°, or even 5° may occur, depending on the density and size of the cloud. After the passage of the cloud the temperature will usually fall rapidly to a point somewhat below that noted before the cloud made its appearance. In this case the passage of the heat radiated from the surface is obstructed by the cloud and turned back or reflected toward the earth, thus raising the temperature at the surface.

The process of radiation is in constant operation. During the day, plants usually receive more heat from the sun than they give off, and consequently grow warmer, while at night more heat is given off than received and their temperature falls. On clear nights this fall in temperature usually continues until the condensation of vapor begins, and if continued until a temperature of 32° Fahr. is reached, frost occurs. The vapor of water, although invisible, is always present in varying quantities in the atmosphere and is a most effective protection against frost; in fact, as remarked by Professor Tyndall many years ago, "were the vapor of water removed from our atmosphere for one single night, even in midsummer, it would be followed by a frost that would surely destroy every particle of vegetation capable of being killed by a freezing temperature." Vapor can always be condensed into water if the temperature is lowered sufficiently, and, as soon as the process of condensation begins, the evolution of heat takes place, which tends to prevent a further fall in temperature. The heat evolved or rendered sensible by the condensation of vapor is enormous, as is evident from the fact that the condensation of sufficient vapor to make a pint of water will evolve enough heat to raise more than five pints from the freezing point to the boiling point. All this heat must be lost by radiation in order that the formation of dew may proceed or the temperature fall. It is therefore a very important fact that when the dew-point, or the temperature at which condensation begins, is reached, the heat evolved by the process prevents, or at least materially retards, a further fall of temperature. Condensation and the consequent evolution of heat begins at a higher temperature when the air contains a large percentage of aqueous vapor, and therefore any process by which the amount of moisture in the atmosphere can be increased will lessen the liability to frost.

Radiation proceeds most rapidly under a clear sky and more rapidly from the surface of plants than from the air about them, so that under favorable conditions the surface of plants is frequently several degrees colder than the surrounding air.

One more factor enters into the problem, viz., the tendency of the air to arrange itself in layers or strata in accordance with its density. On still nights, the colder air, being more dense and consequently heavier, rests on the surface and surrounds the plants, thus increasing their liability to frost. Owing to this fact, a thermometer close to the ground will read frequently 5° to 10° lower than one 8 or 10 feet above the surface. The wind, by keeping the air in motion, mixes the different strata so that a uniform temperature is maintained throughout.

There are, then, three essential conditions favorable to the formation of frost, viz., a clear sky, dry air, and a still night; and when all are present at the critical period the result should not be in doubt. To these of course must be added the proper date, with a general air temperature sufficiently low to make frost within the range of possibility. A clear sky favors frost for the reason, as we have just seen, that clouds offer an obstruction to the passage of the heat rays. The effect of even the thinnest cirrus clouds or haze is appreciable. A comparatively dry air is favorable to the formation of frost, for the reason that the temperature must reach a lower point before dew begins to form (condensation of vapor) with its consequent evolution of heat, than when there is a greater amount of moisture in the air. There is a distinction, however, between dry air and dry soil in regard to the liability to frost. While dry air promotes the formation of frost, a dry soil is not favorable, for the reason that when the soil is moist it loses its heat not only by radiation but also through the process of evaporation. Other things being equal, therefore, frost is more likely to occur on moist than on dry ground, provided, however, the ground be not too moist, in which case the moisture evaporated and added to the air will have a tendency to retard loss of heat both by radiation and by evaporation and thus prevent frost. This point is well understood by cranberry-growers, and it is the general practice to leave the marshes dry when frost threatens unless there is sufficient water at hand thoroughly to saturate the soil.

These are the general principles involved in the formation of frost. All are not equally operative at all times nor in all localities. In many localities in California the topography is such that the problem of diverting the streams of cold air that flow down the valleys is of paramount importance. In the cranberry marshes of Wisconsin the liability to frost is increased by the mass of dry vines that cover the surface, and by the necessity of lowering the surface of the marsh somewhat below that of the surrounding country. Over the western states the most potent factor in the formation of frost is probably the extreme dryness of the atmosphere, which offers little resistance to radiation. In considering the method of protection to be employed in a given locality, the conditions of climate, soil and topography must be studied, and those means selected which seem to offer the most reasonable prospect of success.

How to forecast frost.—Frost warnings are issued by the Weather Bureau whenever the conditions portend the occurrence of frost, and every gardener, fruit-grower and farmer having at hand facilities for protection should place himself in a position to receive these warnings. Frost warnings are, however, necessarily general in character and should be supplemented by a careful study of local climatic conditions and by frequent observations. For this purpose, the wet- and dry-bulb hygrometer, by means of which the dew-point, or the temperature at which the moisture in the air begins to condense, may be determined, is perhaps the most useful. It is to be remembered that, when condensation begins, the fall in temperature is checked by the liberation of the heat previously stored in the vapor through the process of evaporation, so that if the dew-point is much above the freezing point, frost is not likely to occur; if, on the other hand, an observation during the afternoon shows that the dew-point is at or near the freezing point, the sky clear and but little wind, it is reasonable to expect the temperature to fall to the dew-point during the night, and arrangements to protect perishable crops should be made. If, however, it merely approximates the danger point and subsequent observations show no downward tendency, or if clouds appear or the wind rises, action may be safely delayed until the air temperature is within a few degrees of the frost point. There is one point in this connection that cannot be too greatly emphasized, viz., the necessity of making a permanent record of each observation for future reference. This record should include the temperature of the air, the wet-bulb temperature and the dew-point, and the condition of the sky and direction and force of the wind at each observation. If this is done carefully, it will be invaluable on future occasions.

Methods of protection.—Windbreaks.—This method of protection has been employed to some extent in California and is considered efficient when the windbreaks are located properly. The local conditions, however, must be carefully studied and the natural flow of cold currents mapped before a break is located, in order to avoid the formation of still areas or pools which tend to increase rather than diminish the liability to frost. The following description of methods of protection is given by Professor Alexander McAdie, in his work on "Frost Fighting":

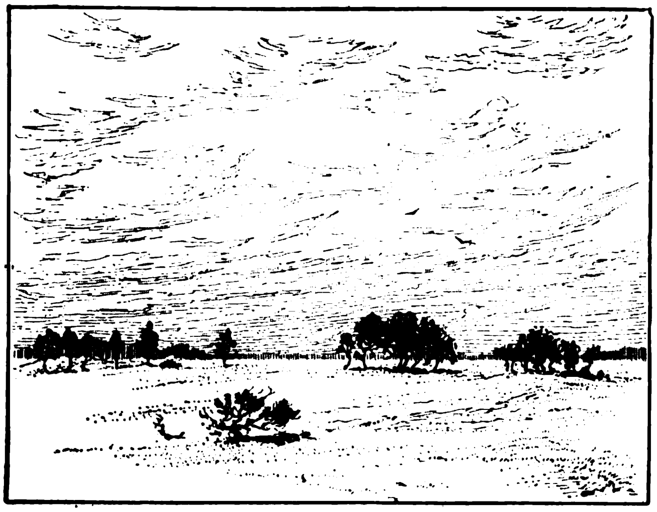


Fig. 702. Cirrus clouds. These are fleecy clouds floating very high in the air.

Fig. 703. Strato-cumulus clouds.

"Warming the air.—A large number of small fires advantageously placed will raise the temperature of the air several degrees. The Riverside Horticultural Club, testing the various methods which were in use in California, came to the conclusion that wire baskets suspended a few feet above the ground, and holding several pounds of coal or charcoal, made an efficient protector. The cost of the wire basket is about ten cents; if forty baskets be used to the acre, the cost of fuel will hardly exceed $2.50. To this must be added the cost of labor during the night and succeeding day in refilling the baskets. This method meets with most favor in southern California. The temperature can be raised certainly 3° or 4° with twenty to forty of these baskets to the acre. Oil-pots have been used and make a hotter fire, but the deposit of lamp-black on the fruit is objectionable.

"Smudge fires.—Damp straw, old wood, prunings, manure, and the like, when burned briskly furnish an effective smoke, and if the material while burning is doused with water, the result is a dense steamy smoke, which serves as a screen to prevent loss of heat by radiation. Wet smudging has been tried in many ways, with varying results. There are many reports of failure, and, on the other hand, some definite results showing the good accomplished by this method. Here, as in other methods of protection, much will depend on a careful study of the local conditions. Many farmers smudge so that a neighbor gets the benefit of their work, while their own fruit remains unprotected. All motion of the air should be noted carefully, and this is sometimes difficult when the smoke is very dense. In some orchards, sacks of old straw soaked with oil are so distributed as to be available for quick lighting.

"Portable smudges have also been used. The one devised by Priestly Hall is probably the most convenient. Mr. Hall has made an effective form of sled, operating under the wet smudge principle. On a sheet-iron sled he has placed a small fire-box, consisting of a grate 4 or 5 inches above the bed of the sled, over which pass iron rods bent in the form of an arch, leaving inclosed a space for the fire about 14 inches in diameter. This fire-box is inclosed in a large corrugated iron box, which has the bed of the sled (about 3 or 4 feet in size) for a bottom, and sides 30 inches high. A door is made in front of the corrugated box to admit fuel for the fire. The box is filled with wet straw or manure and a fire is maintained in the fire-box when the machine is in operation. The cost is about $12; one will do for ten acres.

"Irrigation.—Of all methods proposed for protection excepting wire baskets, irrigation has the largest amount of evidence in its favor. It has been tried in many places with different crops and has generally given satisfaction. Where water is not very plentiful, the method may not always be practicable, but, with this exception, there are many decided advantages in the generous use of water.

"Steam-heat method.—Some growers hold that heat is the one thing that is desired at times of frost, and that the best method is that which produces heat by the simplest and least expensive process. Water, owing to its high specific heat, forms an excellent agency for the temporary storage of heat energy. We have seen that in the wet smudge an attempt is made to utilize the latent heat of vaporization, and theoretically this has always seemed the most advantageous method. A modification of the wet smudge is steam piped through an orchard. This experiment was made by the Wright Brothers at Riverside, Cal., with a 35 horse-power boiler and a main pipe 2 inches in diameter, from which, at right angles every 40 feet, pipes three-quarters of an inch in diameter were extended. It is stated that the temperature was raised 3° when the steam was turned on. It is also said that the coal consumed was not more than the amount used by the basket method.

"Spraying.— After a frost, or rather just before a frost has ended, a spraying device can be used to advantage. Its chief function is to prevent a too rapid warming of the chilled fruit. It is said by horticulturists that even the light coating of ice formed in this way does not seriously damage the fruit. It is very likely that the latent heat of solidification set free by the change from water to ice may play a helpful part; but the chief effect is to prevent a too rapid thawing. In other words, both heat and water should be supplied to the chilled plant slowly, and according to the plant's ability to make good use of them.

"Screening. — All screening or covering devices are in effect modified hothouses, and there is no question but that a thorough protection can be accomplished. The expense is the one objection. Screens are made of light materials, —canvas, muslin, or light wood-work—and have been used with considerable success. At the A. J. Everest ranch, where an elaborate structure of light screens is in use, there is no question as to the value of the protection, but the expense is considerable, averaging perhaps $400 to the acre. The lath covering may be considered as forming a well-ventilated hothouse."

Meteorology on the farm.

Every farmer should give the same attention to local meteorological conditions as is bestowed on the character of the soils or the selection of seed.

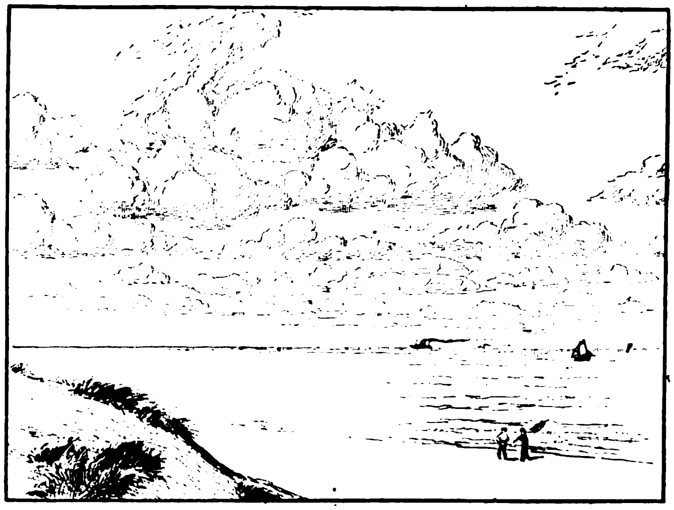


Fig. 704. Cumulus forms. The upper picture shows true cumulus clouds. "Thunder-heads" are of this kind. The lower picture shows rain clouds intermixed, or cumulo-nimbus.

True, he cannot modify or control the elements, but he can often modify or control their effects. A well-kept daily record of the weather, especially the highest and lowest temperatures, the precipitation and the condition of the weather, in connection with a phenological record, is a valuble farm asset. It will often give the clue to a failure or the reason for a success. The instruments necessary for keeping a record of this character are few and inexpensive. The self-registering maximum and minimum thermometers (Fig. 709) are the most convenient, as the highest and lowest temperatures for the 24 hours can be secured at a single observation. The minimum thermometer also indicates the current temperature, just as an ordinary exposed thermometer. The two thermometers, including the necessary supports, can be purchased from any relireliable dealer for about $5. Any receptacle having straight sides will answer for a rain-gage, and the measurements may be made with an ordinary rule. A standard gage (Figs. 701, 755) is much to be preferred, however, and with supports will cost about $5.

The exposure is important. The thermometers should be located in the shade, where there is a free circulation of air, and away from sources of artificial heat. A north porch is usually a good exposure. A box open at front and bottom, placed on the north side of a tree, makes a convenient and suitable shelter The rain-gage should be located in an open space at some distance from buildings, trees or other objects. Thirty or forty feet is sufficient.

Any well-bound blank book of convenient size will answer for keeping the record. It should be ruled so that a single page will contain a month's record, with space at the bottom for the averages of temperature and the total rainfall. Space should be left on the right-hand margin of the page for the phenological record. Here should be entered the date of sowing or planting of each crop, with remarks as to the condition of the soil, the kind of seed, and other factors. The time of germination, cultivation, blossom, fruitage, harvest, and the like, should be noted under the proper date on the record. The data to be entered for the different crops will readily suggest themselves. Such a record, carefully kept, has a distinct, practical and ever-increasing value.

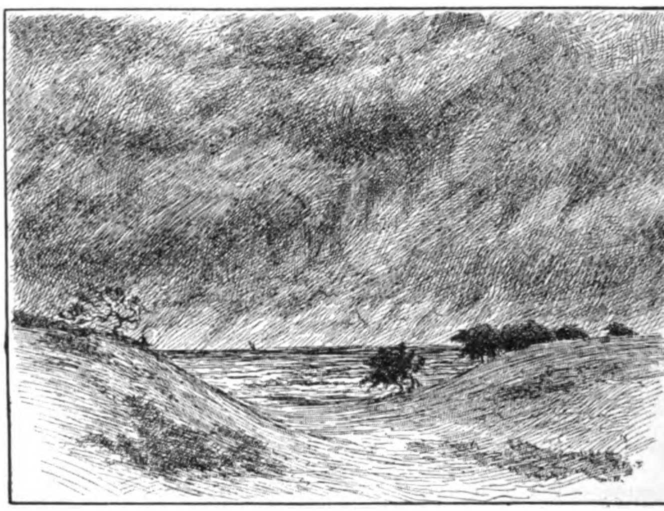


Fig. 705. Nimbus, or rain clouds.

Forecasting the weather from local signs.

Winds.—The weather wisdom of the mariner is proverbial; and nearly every community has its local weather "sharp," who by simple observation of local weather signs, without perhaps the least knowledge of their real significance, has become actually expert in foretelling the weather in his locality. As air movements result from the tendency of the atmosphere at all times to reach a state of equilibrium, the winds always blow from the high places, or the anti-cyclone, toward the low places, called the cyclone- or storm-center, just as water flows down hill. As the general trend of a stream indicates both the direction of its source and its mouth, so the direction of the wind indicates with great precision the location of the storm-center as well as the position of the high pressure area. It must be borne in mind that the wind does not blow in straight lines toward the storm-center but "spirally inward," so that a mass of air starting from the outer edge of a cyclone may possibly make a complete circuit of the storm-center several times before reaching the actual center (Fig. 697). This movement about the center of a storm is always (in the northern hemisphere) in the direction contrary to the movement of the hands of a watch when placed face upward. Thus, a south wind indicates that the storm-center is west of the observer and, as all areas of high and low pressure are carried eastward by the general circulation of the atmosphere, the storm may be expected to pass over or near the place of observation. A north wind indicates that the storm-center is east of the observer and, therefore, will have no further influence on the weather in his vicinity. The following is the general character of the weather to be expected with winds from the different quarters:

Northeast winds generally indicate the approach of a storm from the southwest. These storms gather vast quantities of moisture in passing over or near the Gulf of Mexico, and many of our most violent storms of wind, rain or snow belong to this class. Their approach is almost invariably indicated one to three days in advance by increasing northeasterly winds.

Winds from the southeast are also rain winds, but, as they indicate the approach of a storm from the west or northwest where there is less moisture, they are not usually attended with such heavy precipitation.

Westerly winds indicate that the storm-center is east of the observer and are, therefore, essentially fair-weather winds, the principal difference being that northwest winds are usually cold while southwest winds are usually warm.

If the wind backs or changes direction from easterly to westerly by way of north, it indicates the passage of a storm to the south of the observer; if, on the other hand, it veers or changes from easterly to westerly by way of south, it indicates the passage of a storm to the north of the observer. When the wind is south and veers to westerly, fair weather will follow; but when it backs to easterly, foul weather may be expected.

Clouds.—The presence of clouds indicates that the process of condensation is in operation and needs only to be effected more rapidly to produce rain or snow. They show very clearly the stage to which the process has advanced and therefore afford excellent indications of the approaching weather. For this purpose the true cirrus (Fig. 702) and cirro-stratus clouds are the most valuable. They are formed at high elevations by the low temperature which condenses the moisture that overflows from the storm-center and are carried eastward by the prevailing winds often far in advance of an approaching storm. If the storm which gives rise to these clouds has sufficient strength, rain or snow will usually follow within eighteen to thirty-six hours after their appearance. In such cases the cloudiness becomes gradually more dense until precipitation begins.

The lower clouds possess but little value as rain indicators, for the reason that they usually come with the rain or precede by very short periods the beginning of precipitation.

The barometer as a weather indicator.

The mercurial barometer is, of course, the standard instrument used for all observations where great accuracy is required, but a good aneroid barometer, which can be purchased for $10 to $15, will answer all practical purposes. In the use of an aneroid barometer, little attention should be given to the legends, such as fair, changeable, stormy, and the like, usually printed on the face of the instrument, for the reason that the direction and rapidity of the barometric changes as indicated by the barometer are of much more importance in forecasting the weather than the actual reading at a given time. As low barometer readings are usually attended with stormy weather and high barometer readings with clearing or fair weather, it follows that as a rule falling barometer indicates wind, rain or snow and rising barometer clearing or fair weather.

The following table, by Professor E. B. Garriott, summarizes the barometer and wind indications for the United States:

Barometer reduced to sea-level (inches)	Direction of wind	Character of weather indicated
30.10 to 30.20, and steady	S. W. to N. W.	Fair, with slight temperature changes for 1 or 2 days.
30.10 to 30.20, and rising rapidly. .	S. W. to N. W.	Fair, followed within 2 days by warmer and rain.
30.10 to 30.20, and falling slowly . .	S. W. to N. W.	Warmer, with rain in 24 to 36 hours.
30.10 to 30.20, and falling rapidly .	S. W. to N. W.	Warmer, with rain in 18 to 24 hours.
30.20 and above, and stationary . .	S. W. to N. W.	Continued fair, with no decided change in temperature.
30.20 and above, and falling slowly .	S. W. to N. W.	Slowly rising temperature, and fair for 2 days.
30.10 to 30.20, and falling slowly . .	S. to S. E.	Rain within 24 hours.
30.10 to 30.20, and falling rapidly .	S. to S. E.	Wind increasing in force, with rain within 12 to 24 hours.
30.10 to 30.20, and falling slowly. .	S. E. to N. E.	Rain in 12 to 18 hours.
30.10 to 30.20, and falling rapidly .	S. E. to N. E.	Increasing wind, with rain within 12 hours.
30.10 and above, and falling slowly .	E. to N. E.	In summer with light winds, rain may not fall for several days. In winter, rain within 24 hours.
30.10 and above, and falling rapidly.	E. to N. E.	In summer, rain probable within 24 hours. In winter, rain or snow, with increasing winds will often set in when the barometer begins to fall and the wind sets in from the N. E.
30.00 or below, and falling slowly .	S. E. to N. E.	Rain will continue for 1 or 2 days.
30.00 or below, and falling rapidly .	S. E. to N. E.	Rain, with high winds, followed within 24 hours by clearing and cooler.
30.00 or below, and rising slowly . .	S. to S. W.	Clearing within a few hours and continued fair for several days.
29.80 or below, and falling rapidly .	S. to E.	Severe storm of wind and rain or snow imminent, followed within 24 hours by clearing and colder.
29.80 or below, and falling rapidly .	E. to N.	Severe northeast gales and heavy rain or snow, followed in winter by a cold-wave.
29.80 or below, and rising rapidly	going to W.	Clearing and colder.

In the use of this table it is necessary that the barometer be so adjusted as to give sea-level readings. If in doubt, proceed as follows: Make a barometer reading at 8 A. M. (75th meridian or eastern time, which is 7 A. M. local time at Chicago, 6 A. M. at Denver and 5 A. M. at San Francisco) each day for 10 days. Mail a copy of these readings to the nearest local office of the Weather Bureau, with the request that these readings be compared with the official barometer readings made on the same dates and that the proper correction to reduce the readings to sea-level be furnished. With this correction at hand, the hand or pointer on the dial of the barometer can be moved readily to the proper point so as to indicate sea-level pressures in the future. Example: If the barometer reads 29.92 and the correction is + (plus) .25, the indicator should be moved to 30.17; if the correction is — (minus) .12, the hand should be moved to 29.80. The adjustment is easily accomplished by inserting a small screw-driver in the hole in the back of the instrument and turning the adjusting pin until the hand or indicator rests at the proper reading. As the accuracy of an aneroid barometer depends on the mechanical construction of the different parts, it may get out of adjustment occasionally. Some instruments give accurate readings for many years, but it is well to compare an aneroid barometer with a mercurial instrument once every two years at least, and oftener if there is any suspicion of error. This can be accomplished by taking a series of readings, as above described, and comparing these readings with the readings shown by the isobars on the daily weather map for the same date, or the readings can be mailed to a local office of the Weather Bureau as above suggested.

Popular notions about the weather.

Influence of sun-spots on the weather.—While the underlying cause for the appearance of spots on the face of the sun is not understood, a well-established period of maximum frequency is now recognized. This period or cycle is eleven years and one month in duration (Todd). Since the sun is the great source of heat, and all meteorological phenomena are the result of the unequal heating of the different parts of the earth's surface, it would seem natural to suppose that any visible change on the surface of the sun would produce a noticeable effect on the atmosphere of the earth. Nevertheless, the results of numerous and varied studies of this problem, made in many parts of the world, have not come up to expectations in this regard and on the whole tend, rather, to show that the influence of sun-spots on the weather is insignificant. Dr. Julius Hann says, "Even in the most marked cases the only thing that can be considered as proved is that there are traces of parallelism in the march of certain meteorological elements and that of the sun-spot period. A forecast of the weather based on the sun-spot period is, therefore, still impracticable."

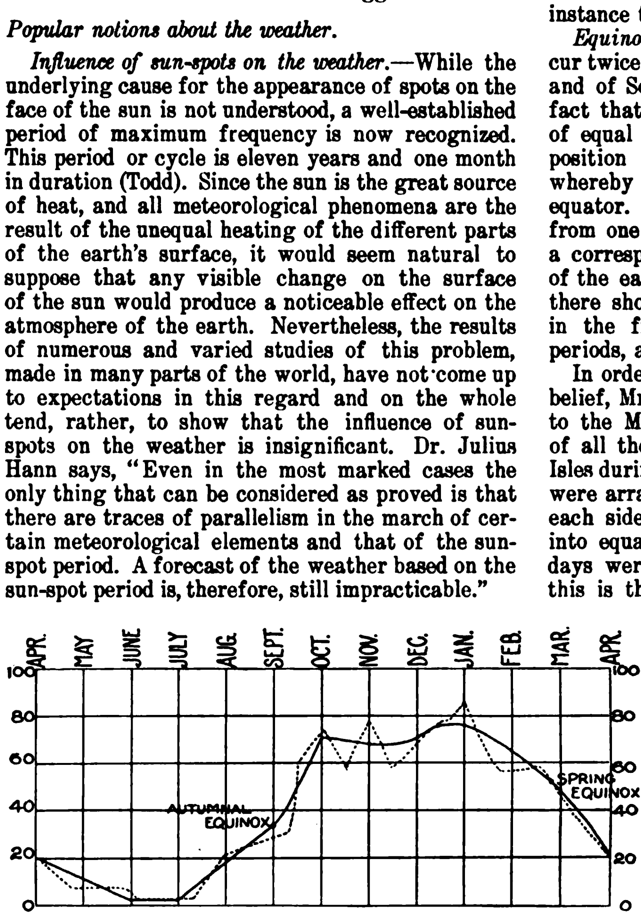


Fig. 706. The progress of storm-frequency throughout the year. The horizontal lines represent the number of storms occurring in each period, as indicated by the figures at the ends of the lines. (Robert H. Scott.)

The moon and the weather.—The belief that the moon exerts a powerful influence on terrestrial weather is almost universal, and in combating this belief one is always met with the question, "The moon influences the tides; why not the weather?" It is admitted that the moon does create a tide in the atmosphere. It has been measured. It amounts to just four-thousandths of an inch in the height of the barometer (Russell). This alone should show its insignificance in the production of storms.

Probably the first serious attempt to establish a relation between the moon and the weather was made by Sir John Herschel. He constructed a table which indicated to his satisfaction at the time that the moon's influence on terrestrial weather was appreciable. In later years, with more extended data, he reversed his former conclusions. Herschel the younger repudiated the idea that his father was the author of the first table. He says that it is impossible that Sir John could have been guilty of such monstrous folly—which is probably true. Since that time there have been many attempts to show a relation between the phases of the moon and the weather changes, but in every instance the results have been negative.

Equinoctial storms.—The equinoctial periods occur twice each year, about the twenty-first of March and of September, and take their name from the fact that on these dates the days and nights are of equal duration. This results from the relative position of the earth with respect to the sun, whereby the sun's rays fall directly on the earth's equator. It is well understood that the change from one season to another is brought about by a corresponding change in the relative positions of the earth and the sun, but it is not clear why there should be any tendency toward an increase in the frequency of storms at the equinoctial periods, as appears to be the popular belief.

In order to test the foundation for this general belief, Mr. Robert H. Scott, A.M., F.R.S., secretary to the Meteorological Council, made a catalogue of all the severe storms reported in the British Isles during a period of seventeen years. The dates were arranged in 15-day periods, taking 7 days on each side of the equinox and dividing the year into equal periods of 15 days each. The extra 5 days were omitted at the beginning of July, as this is the time of year most free from storms. These data are graphically shown on the accompanying diagram (Fig. 706). The horizontal lines represent the number of storms occurring in each period, as indicated by the figures at the end of the lines. The vertical lines correspond to the middle days of each month. The heavy curved line represents the annual march of storm frequency, and a glance at this curve is sufficient to show that there is no marked increase in the number of storms occurring at either equinox. It will be noted, however, that the frequency of storms at the time of the spring equinox is nearly double that of the autumn, and that both equinoxes are periods of change in storm frequency. The difference is that during the spring equinoctial period there is a gradual decline in the number of storms, while at the autumnal equinox the increase is very marked. Accordingly, persons who contemplate a sea voyage and wait until the autumnal equinox is over materially increase their chances of falling in with stormy weather; but in the spring it would be wise apparently to wait until the equinoctial period is well over if one wishes to have calm weather at sea.

The results of Mr. Scott's investigation have been confirmed by Mr. Prince and other independent investigators, so that the question of equinoctial storms may be considered as settled. Mr. Scott has published a work on "Meteorology" in which the details of his investigation are given.

Long-range or almanac forecasts. — The prediction of the weather for a season or a year in advance has always been attractive to the meteorologist, but as yet all efforts in this direction have been unsuccessful. The public demand for forecasts of this character because of the evident utility of a forecast that would outline correctly the weather for a season in advance, has given rise to a number of so-called long-range forecasters, each one of whom purports to be in possession of a knowledge of certain physical laws, which are yet unknown to the scientific world, whereby he is enabled to determine the specific and general character of the weather for a year or more in advance. These systems are usually founded on the assumed influence of planetary equinoxes. As we have just seen that the influence of the equinoctial periods on the weather of our own planet is negative, we may well question the supposed influence exerted on our atmosphere by those remote members of our planetary system. One of these systems of long-range forecasting, which has apparently enjoyed the popular favor, is based for the most part on the supposed influence of a planet that has never been seen by any reputable astronomer and which, in the opinion of those competent to judge, does not exist. It is, therefore, unnecessary to say that forecasts based on systems of this character should receive no credence whatever. That the changing weather conditions are under the control of natural laws, no one for a moment doubts, and it is not impossible that a future generation may produce a Newton or a Kepler of meteorology who will read the weather as a modern astronomer reads the heavens; but the present affords neither the time nor the man.

Meteorological services of the world.

The orders of the meteorological stations, as defined by the International Meteorological Congress held at Vienna in 1873, are as follows:

Central Office, or central institute, is the chief office entrusted by the government with the management, collection and publication of the meteorological observations of the country.

Central station is a subordinate center for the management and collection of observations from a certain province.

A station of the first order is an observatory in which, without collection of observations from other stations, meteorological observations are conducted on a great scale, either by hourly readings or by the use of self-recording instruments.

Stations of the second order are the stations where complete and regular observations on the usual meteorological elements, viz., pressure, temperature and humidity of the air, wind, cloud, rain and hydrometeors, etc., are conducted.

Stations of the third order are the observing stations, where only a greater or less part of these elements are observed.

America.

United States.—Daily observations of the weather were started by private individuals in the United States as early as 1644 (Fassig), and in 1816 the medical staff of the army began the somewhat systematic collection of climatological data at the various army posts. During the following fifty years, the work was conducted at different times by some of the larger state institutions, the Patent Office, and the Smithsonian Institution. No predictions of the weather were attempted until 1869, when Professor Cleveland Abbe, with the coöperation of the Cincinnati Chamber of Commerce, began the collection of weather observations by telegraph and the issue of forecasts. In the following year, Congress passed a resolution authorizing the Secretary of War to establish observing stations, gather reports and issue warnings. This work was placed under the direction of the Chief Signal Officer of the Army, and the first official forecast was prepared by Dr. I. A. Lapham, assistant to the Chief Signal Officer, and stationed at Chicago, in November, 1871. In the first twenty years of its development, the work was conducted by the signal corps of the army, but the demand for a strictly scientific bureau, unhampered by regulations of a military character, resulted in its reorganization in 1891, and the establishment of the present Weather Bureau as a branch of the Department of Agriculture.

The total number of commissioned employees June 30, 1905, was 680; non-commissioned employees, or those giving only part of their time to the work, 914; and the number of coöperative observers connected with the Climatological Service not receiving compensation was 3,665. The Central Office is located at Washington, D. C. There are about 195 stations of the first order where the principal meteorological elements are regularly observed and recorded, and about 4,000 stations doing voluntary work. There is one station, located at Mount Weather, Virginia, devoted exclusively to research and experimental work. Practical weather forecasting has always been the leading feature of the organization, and the percentage of success in 1898 was as follows: for weather forecasts, 36 hours in advance, 85; temperature, 83; for weather, 48 hours in advance, 81; temperature, 85; for wind signals 24 hours in advance, 80; cold-wave warnings, 75; for river and flood warnings the percentage of successful predictions was 100.

The appropriation for the support of the Weather Bureau in 1905 was $1,392,990. The annual saving of life and property is known to be very great. An estimate of the money value of the property saved by means of the warnings issued is difficult, but an annual saving of $30,000,000 is considered conservative.

Porto Rico and *Hawaii* are organized as sections of the United States Weather Bureau. The section centers are located at San Juan and Honolulu respectively. [For Philippine Islands, see Asia.]

Canada.—The meteorological observations were conducted in Canada by different schools until 1871, when the government took charge of the work, and since that time the service has grown rapidly. In 1898 there were 4 stations of the first order, 65 of the second order, 206 of the third order, and 89 rainfall stations. The service coöperates very extensively with that of the United States.

Cuba.—The Cuban government formed a weather service in 1902, and now has one first-order station in Havana and a second-order station in each of the other four provinces. The principal work of this Bureau consists in issuing warnings for the West Indian hurricanes and publishing the crop bulletins.

Mexico.—The meteorological observations seem to have been made in Mexico more or less continuously from 1768 to 1877, when the Central Meteorological Observatory was founded, and all the other stations were gradually absorbed into the system. Attached to the organization there are one first-order station, 28 second-order stations, and many stations of what may be called third order. The service coöperates with that of the United States, and depends on the latter for its storm warnings.

Argentine Republic.—The Argentine Meteorological Office was founded in 1872, and is the most complete organization at present in South America. Attached to the office there were, in 1898, one first-order station, 10 second-order stations, 24 third-order stations, and 136 fourth-order stations.

Brazil.—The system in Brazil seems at present to be undeveloped. The Central Meteorological Office was established in the Ministry of Marine in 1885 under the director. Capt. A. P. Pinheiro, who died in June, 1896, and whose death was a very great loss to the service. There is one station of the first order, but there does not appear to be any regular system of stations attached to it, though there are independent organizations in the different provinces.

Europe.

Austro-Hungarian Empire.—The Central Institute for Meteorological and Terrestrial Magnetism at Vienna was established in 1851. The present director is Professor J. M. Pernter, who in 1897 succeeded Professor Hann. The stations number over 500, of which 25 are first order. A large number of investigations have been completed. The yearly expense to the government is about $12,000.

Until 1870 the Hungarian Weather Service formed part of that of Austria, but in April of that year it was formed into a separate system, with an office at Budapest. The number of stations attached to the office is 321, of which one is first order and the remainder second and third orders. A daily weather report is published and many observations have been discussed. The expense to the government of the service is about $10,000.

Belgium.—The Royal Observatory of Brussels, now situated at Uccle, Belgium, was founded in 1826, but did not commence regular work until 1833. From the first, meteorology occupied a large place. Stations have been established gradually, until now there are about 70 climatological stations and 250 rainfall stations attached to the Royal Observatory. Storm warnings are issued and forecasting is undertaken, but no percentage of success is published. Numerous publications relating to the climate of Belgium have been issued. The allowance for meteorology in 1897 amounted to about $10,000.

British Isles.—In Great Britain the Meteorological Department of the Board of Trade of London was established in 1854, with Admiral Fitz-Roy as its chief. After the death of Admiral Fitz-Roy in 1867, the government placed the office under the management of a Committee of the Royal Society, and in 1877 the office was reconstituted and placed under the management of the Meteorological Council. The duties of the office relate to marine meteorology, weather telegraphy and land meteorology. The stations attached to the office numbered 269 in 1898, of which about one-half were first order and the remainder second or third order. The total number of reporting stations in the British Isles in 1898, including rainfall stations, was nearly 4,000. Forecasting is undertaken, the percentage of successful forecasts for the 10 years 1887–96 being 81.6, and for storm warnings for the same period, 87.3. The publications are numerous. The government grant is about $80,000 and free printing.

Denmark.—The Danish Meteorological Institute was founded at Copenhagen in 1872, and is divided into five departments: (1) Climatology, (2) Weather Service, (3) Nautical Service, (4) Mareographic Observations, and (5) Magnetical Observations. There are 282 stations attached to the institute, of which 107 are rainfall stations. Thirty-one of the stations are in the colonies of Faroe, Iceland, and Greenland. Weather forecasting is undertaken and the percentage of success is 82. Many investigations have been published. The amount of the government grant is about $22,000.

France.—The Meteorological Service of France was established in 1855 as a special branch of the observatory of Paris, and was constituted a separate service in 1878. The stations attached to the service number 2,236, and comprise 12 first order, 5 mountain stations, 183 second order, and 2,036 third order. Forecasts are issued, and for 1897 a large percentage of success, viz., 91, was claimed. Numerous investigations have been undertaken; the expense of the service is about $40,000.

German Empire.—In the German Empire there is a very extensive system of coöperation between several nearly independent meteorological services, the principal ones being those of Hamburg, Prussia, Saxony and Baden. The Hamburg service is the imperial system of the Empire, and manages marine meteorology, storm warnings and forecasts. There are several thousand stations connected with the different services. Weather forecasts are made only to a limited extent, except in the Hamburg service, and even there no estimate of the percentage of success can be given. Numerous publications are issued, and they generally contain the results of some very interesting investigations.

No estimates of the costs to the governments are at hand, as many of the expenses are borne by the different departments.

Greece. — The Meteorological Observatory at Athens, Greece, was founded as a second-order station in 1847, and up to 1890 there were practically only three stations attached to it. In the latter year the Observatory was completed, and it was provided with self-registering instruments in 1893. In the same year, 19 additional second-order stations were established, which send two telegraphic reports daily. Besides these, 55 foreign stations in Europe, Asia Minor and Africa send daily telegraphic reports for a Meteorological Bulletin. The publications of the Observatory deal principally with the observations at Athens, and preparations are being made for the publication of the observations of the provincial stations. The government allowance is very small.

Italy.—The Meteorological Service of Italy is extremely complicated. Observations were begun at the Collegio Romano, the present seat of the Central Office in Rome, in 1787. The government took up meteorology by a decree on December 13, 1863, and appointed a Committee for Weather Telegraphy. The stations attached to the Central Office number 553. Weather forecasting is undertaken, but the percentage of success and the cost of the service are not published.

Netherlands.—The Royal Meteorological Institute of the Netherlands was founded at Utrecht in 1854. The work is divided into two parts,—one for observation on shore and the other for observation on ship. There are attached to the Institute about 306 stations, of which 6 are first-order stations. Forecast work is conducted, but the success of the work has not been figured out in the percentage. The Institute is a government establishment, and the annual grant is about $18,000.

Portugal.—The Observatory of the Infante Dom Luiz at Lisbon, Portugal, was founded in 1854, and the present building was erected in 1863. There are 24 stations attached to the Observatory; 15 on the continent and 9 on the adjacent islands. All the stations except the colonial ones send daily telegrams. By their aid and the telegrams from Spain, France and England, daily forecasts are issued. The percentage of successful forecasts is not calculated. Various memoirs have been at times published, some of which rank very high, and some very interesting investigations are in progress. The expense is about $9,000.

Roumania.—The Roumanian Meteorological Institute was founded in 1884. Attached to the office are 357 stations, one being a first-order station. The annual publications contain the results of valuable investigations relating to climate.

Russia.—In Russia there is a very extensive system under the direction of the Observatory at Pavlovsk. Weather forecasting is undertaken and the percentage of success is about 80. There are three stations of the first order, over 800 of the second order, and nearly 3,000 of the third order. The expense of the system, including the observatories, is about $250,000.

Spain.—Practically no meteorological work was done in Spain until 1870, when 23 stations, with the Madrid Observatory as Central Station, were established by a royal decree. The department has been reorganized twice since that time, and now consists of 45 stations, two of the first order and 43 of the second order. Forecasting is undertaken, but the percentage of success is not known. The expenses of the system cannot be stated, as they are exclusive of the salaries of the Central Station, and of telegraphy, which is free.

Sweden and Norway.—Both Sweden and Norway have developed very efficient meteorological services since 1860. Each service has attached to it between 400 and 500 stations, and the success of their forecast work varies between 80 and 85 per cent. Many interesting publications have been issued. The government grant in each case is about $10,000.

Switzerland.— In 1824 the Swiss Society of Natural Philosophy had 12 meteorological stations superintended by a committee. These were given up thirteen years later for lack of funds. During later years the society established different stations, but they were practically suppressed by the establishment of the Swiss Meteorological Office in 1880. The stations attached to the office number about 400. The percentage of success of forecast is 70 for complete success. The annual vote from the government is about $15,000.

Asia.

India.—The most important meteorological service in Asia is that of India. Previous to 1865 observations in India were for the most part conducted by the six observatories established by the East India Company for purely scientific purposes, the oldest record being that of the Madras Observatory established in 1792. Meteorological observations were begun at this institution in 1796 and have been continued to the present. In 1865, a system of independent provincial departments was established, and in 1875 the work was reorganized and unified under the direction of Mr. H. F. Blanford, Meteorological Reporter for the government of India. The service as a whole is organized thoroughly and is highly efficient. In 1901, the number of stations working under or in coöperation with the department, as given by Mr. John Eliot in his administrative report for 1900–1901, was 230, and the number of ports on the coast where storm-warning signal flags were displayed was 45. Observations are collected daily by telegraph, and weather maps and charts issued. The forecasting of the beginning and character of the monsoon rains has been a leading feature of the service since its introduction by Mr. Eliot in 1878. These forecasts are issued in May or June, some weeks before the setting of the southwest monsoon, and it is remarkable that in thirteen years there has been only one failure. A number of important investigations have been undertaken both by Mr. Blanford and Mr. Eliot, the results of which form valuable contributions to the science of meteorology.

Philippine Islands.

The Philippine Weather Bureau is organized under the United States Department of the Interior, directly under the control of the local Secretary of the Interior, through whom it reports to the Governor of the Philippine islands and the Bureau of Insular Affairs at Washington. The Manila Observatory is the Central Office, and at the time of the reorganization of the service in 1901 it had attached to it 9 first-order stations, 25 second-order stations, 17 third-order stations, and 21 special rainfall stations. A daily weather map is prepared from telegraphic observations, and forecasts are made, special attention being given to the prediction of baguios, or typhoons. The annual appropriation for salaries approximates $38,000, and for maintenance $13,000. (See Monthly Weather Review, August, 1901, and October, 1903.)

The remaining meteorological services of Asia are those of Hong Kong, Japan and Java.

Australia and Africa.

Previous to 1906 there were seven independent weather services in Australia, viz.: New South Wales, New Zealand, Qeensland, South Australia, Tasmania, Victoria and West Australia. Several of these services were very efficient. During 1906 legislation was enacted looking to a federation of these services and a reorganization on practically the same line as the United States Weather Bureau.

The meteorological services of Africa are those of Mauritius, Cape Colony and Natal.

Summary.

These, it is thought, are all the services in the world at present which are government organizations. There are many private or semi-private observatories and colleges which make very valuable investigations, and some of these coöperate.

Literature.

This article is little more than a compilation. When practicable, the authorship or authority has been given in the text. In some instances, excerpts are used from publications prepared under the direction of the Chief of the United States Weather Bureau, of which the individual authorship was unknown. The following acknowledgements are due: Willis L. Moore, Chief of United States Weather Bureau, Climate, Its Physical Basis and Controlling Factors; James Knealey, in Department of Agriculture Yearbook, 1903, Weather Bureau Stations and Their Duties; Frank H. Bigelow, Storms, Storm Tracks and Weather Forecasting; Edward B. Garriott, Long-range Weather Forecasts, Weather Folk-Lore and Local Weather Signs; W. H. Hammon, Frost, When to Expect it and How to Lessen the Injury Therefrom; Alexander McAdie, Frost Fighting. The discussion relating to meteorological services of the world was mostly compiled by W. C. Devereaux, Local Forecaster of the Weather Bureau, and formerly Instructor in Meteorology at Cornell University. [For discussion of protection from lightning, see Roberts' "Farmstead."]

CHAPTER XVIII

THE ATMOSPHERE AND ITS PHENOMENA

By CLEVELAND ABBE, Jr.

CLIMATE AND WEATHER are of more concern to the agriculturist than the soil itself. The consideration of weather is included under the general term of meteorology. This term is applied to the study of all those phenomena which have to deal with what we ordinarily understand as the weather. The special student of the weather, however, generally restricts the meaning of the term meteorology to his studies into the laws controlling the conditions of the atmosphere at any given period of time. While the study of these laws, especially the fundamental laws of meteorology, is of the utmost importance for one who would understand the conditions of the atmosphere of the earth which exert the most influence on the crops produced by the soil, yet the agricultural interests are most concerned with that division or subdivision of meteorology which treats of the climate or climates of the earth's surface. By climate is here meant the sum total of all those phenomena of the atmosphere which characterize the average condition of the atmosphere throughout a series of years at any one place on the surface of the earth. It is evident that what we usually call the weather is only a single phase in the succession of phenomena which repeat themselves more or less regularly from year to year. Climatology thus has for its end the study of the average conditions of the atmosphere at different points on the surface of the earth, together with any variations from those average conditions that may occur at that place during long intervals of time. Meteorology, on the

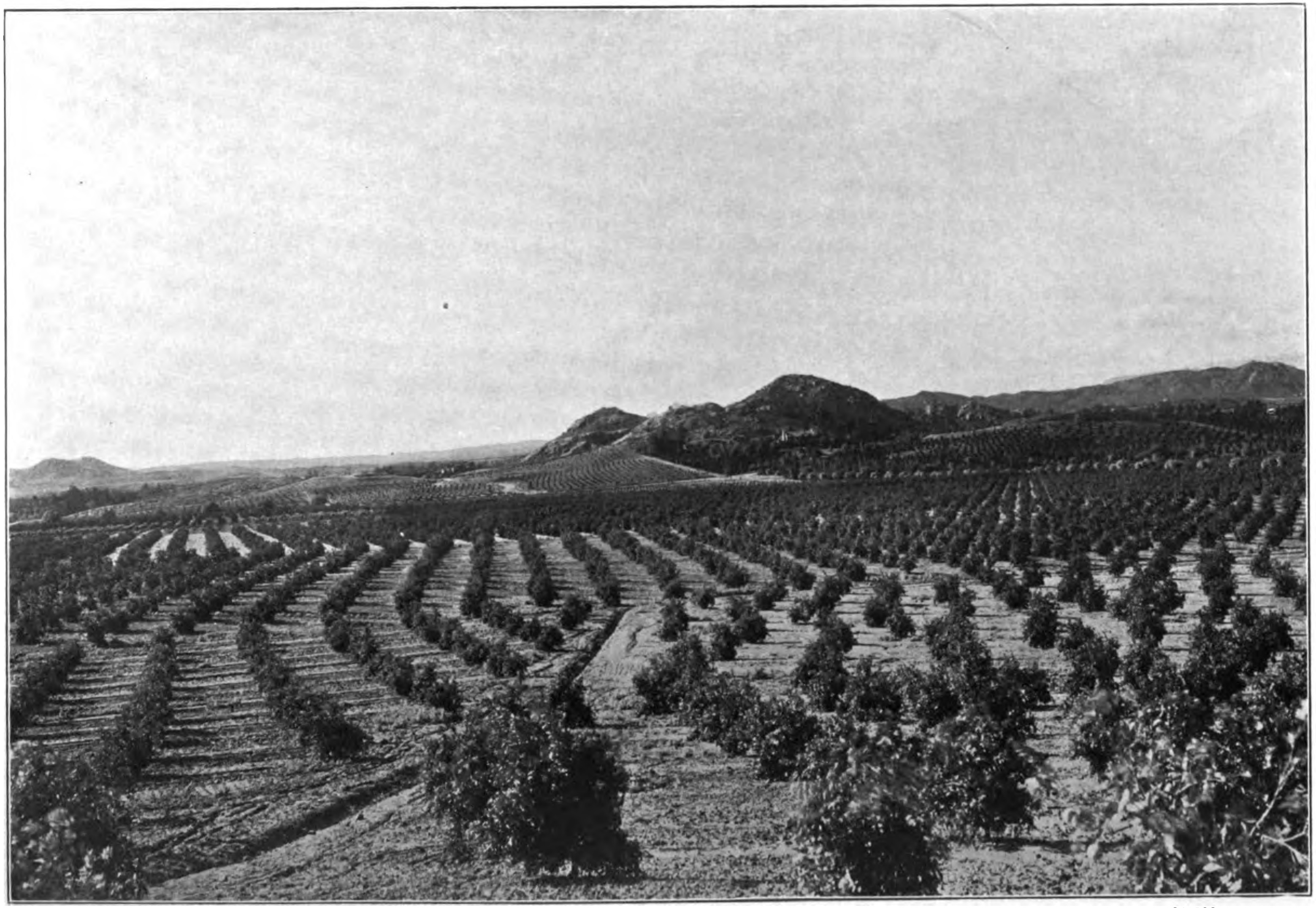


Plate XXIV. Fruit-growing in southern California. Orange groves, three to ten years of age, Riverside. These groves are valued at $1,000 to $1,800 per acre other hand, tries to explain the various atmospherical phenomena by means of known physical laws, and endeavors to discover the causes underlying the succession of these atmospheric phenomena. It is evident that a true appreciation of the phenomena treated of in a climatological discussion involves some knowledge of those meteorological laws which may be regarded as fundamental. On the other hand, an adequate understanding of the climatological peculiarities of the different parts of the surface of the earth does not involve extended studies into the more or less theoretical investigations which the study of meteorology implies.

The climatic elements.—The various atmospheric processes and conditions whose interactions determine the climate of any place are called the climatic elements or climatic factors. The most important of these elements are the temperature of the atmosphere, the moisture suspended in the atmosphere, and the movements of the atmosphere, which we generally consider either as winds or as storms. In making a scientific study of climatic phenomena, we have progressed beyond the stage where it is sufficient to say that the winters of a given region are very severe or that the summer is windy and changeable, and we need now, as far as possible, to have these elements of the climate measured and expressed in some definite system of notation. Consequently, in the following pages the fundamental climatological elements will be compared over different regions not only in general terms, but by using quantitative numerical expressions as far as possible. The discussion of climatology will be preceded by a brief study of the general and fundamental meteorological laws, without which the climatological status would remain quite unexplained.

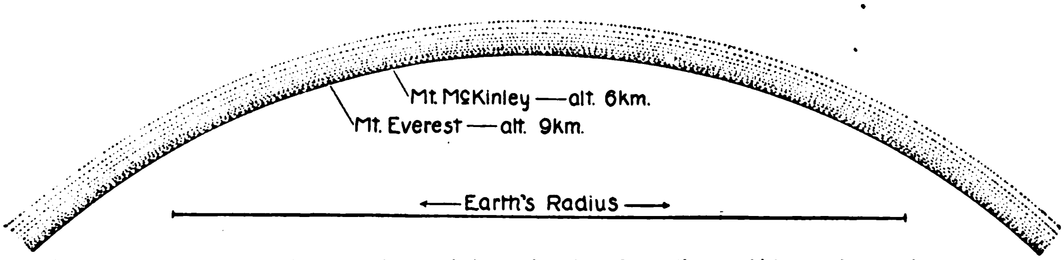


Fig. 707. The earth's atmosphere: To show,—First, relation of earth's radius to thickness of atmosphere; second, vertical decrease of density of atmosphere; third, vertical extent of crustal irregularities.

Section I. The Atmosphere in General

Physical character of the atmosphere.

Our planet is surrounded by an envelope made up of matter in two different states: the visible part of this envelope consists of the liquid water making up the oceans, and lies next to the rocky skeleton of the globe itself. Outside the water, resting in part on it and in part on the land, is an invisible, intangible substance in the gaseous state, whose presence is chiefly made known to us by its effects on the solid and liquid parts of the globe. This gaseous part of the envelope we call the atmosphere, a name taken from two Greek words meaning that part of the globe which we can breathe. It is this invisible, gaseous envelope which is the special object of the study of meteorology, and it is the changes in the conditions of this atmosphere which, with their effects on the animate and the inanimate objects of the lands, will especially interest us in the study of climatology. The gaseous atmosphere is evidently distributed above the surface of the solid and the liquid globe. Wherever man has traveled he has found that animal and vegetable life can exist and that fire can burn, and these three phenomena are directly dependent on the presence or absence of this invisible gas we call the air. (Fig. 707.)

The vertical distribution of the atmosphere.

While we may be certain that everywhere over the surface of the earth the air lies in close contact with the ground or the ocean, it is not so evident to our senses to what vertical distance above the surface of the earth this atmosphere reaches. Physical experiments and measurements have proved that this invisible gas has density, that it has of itself weight, just as water or rock; and these same experiments have shown that the density of the atmosphere decreases as we rise or climb farther and farther above the surface of the earth. If the density of the atmosphere decreases as we rise into it, we would naturally expect to find either that at some point the atmosphere stops or that it grows rapidly thinner and thinner until it finally merges gradually into nothing. There are a number of phenomena which enable us to measure more or less accurately the height to which the atmosphere reaches above the surface of the earth. Of these the most familiar is twilight, which endures for a greater or less length of time after the sun has really set for any given point on the surface of the earth. The phenomenon of twilight is of itself a proof that the earth has an atmosphere, for twilight results from the bending of the light rays of the sun out of their straight course into a curved course, which finally brings some of them to the surface of the earth.

Those rays from the sun which strike the earth at the points T and C in Fig. 708 would go on into space, never illuminating any parts of the surface of the earth that lie beyond the line TEC, while rays from the sun which passed the earth even at short distances above the points T and C would never illuminate the earth at all. The presence of the atmosphere about the earth, however,

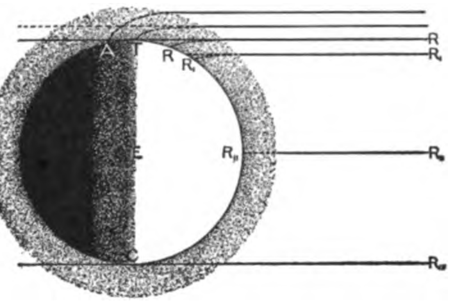


Fig. 708. Explanation of the phenomenon of twilight. The rays of light, except those striking the earth at an angle of 90°, are refracted toward the earth. In this way, the rays passing above the circle TEC are bent downward, producing a twilight band back of this circle. If it were not for the atmosphere, all rays passing above TEC would pass beyond the earth and be lost.

refracts those rays which would otherwise escape the earth altogether, and turns some of their light, striking the surface of the earth behind the line TEC; for example, at A. While all that half of the earth lying to the left of the line TC receives no direct light from the sun, yet a narrow band immediately behind the twilight circle (the line TC) receives a part of the light which is passing through the upper layers of the atmosphere of the earth. Measurements of the width of this twilight band have indicated that the height of the highest layers of the atmosphere that are able to turn light rays down to the surface of the earth must be about 63 km. (a kilometer is 0.621 of a mile), but on very clear winter days it has been found that the atmosphere refracted light to the earth from altitudes even as great as 74 km.

Since 1885 science has been aware of a peculiar phenomenon observed in the northern heavens in the nights that follow the longest days of summer. This phenomenon was nothing less than high floating clouds that reflected sunlight to the earth even at midnight. These clouds, which have been observed from May to the end of July in the northern hemisphere, and in December in the southern hemisphere, are characteristic of the higher parallels of latitude, and have been shown by trigonometrical measurements from photographs of them to float at an altitude of 83 km. The northern lights (aurora) have also been observed and the altitudes of their displays measured; and if they are directly dependent on the atmosphere of the earth for their visibility, they prove the same to have an altitude of not less than 200 km., although the displays are usually found to have an altitude of 60 km.

One of the most interesting lines of evidence as to the altitude of the atmosphere is furnished by the meteors, which are particularly noticeable at certain seasons of the year. These meteors consist either of rock or metallic masses precisely similar in character to those found on the earth, and owe their brilliancy to the high temperatures to which their surfaces are raised by their rapid flight through the resisting atmosphere. Of course, they do not become visible until they reach a level in the atmosphere of sufficient density to make their outer surfaces incandescent, but the measurements of the altitudes at which a large number of these meteors have first become visible show that the atmosphere possesses some density even as far as 250 or 300 km. above the level of the ocean.

There is one more phenomenon which enables us to measure the altitude of the atmosphere of the earth, namely, the effect that the atmosphere has in diminishing the light that comes from the sun to the moon at the time of a lunar eclipse. If there were no atmosphere about the earth the moon should shine brightly up to the very instant when the earth reaches its first position between the sun and the moon. But it has been observed that the brilliancy of the moon suffers a distinct decrease, certainly as much as three minutes before the earth's shadow proper touches the moon, and it may be that a decrease in the lunar brilliancy occurs as long as fifteen minutes before that period. This can mean only that the rays of the sun that passed the earth to the moon are interrupted in their course by the atmosphere some time before the opaque body of the earth comes in the way. Assuming that the shorter interval of time is the correct one, it appears that the terrestrial atmosphere must have an altitude of not less than 300 km., in order to produce so early a diminution of the brilliancy of the moon.

The composition of the atmosphere.

The atmosphere consists, for the most part, of constant quantities of substances which, under ordinary conditions of temperature and pressure, remain in a gaseous state. The gases most common in the atmosphere are nitrogen, oxygen and carbon dioxid, while locally considerable quantities of ozone and ammonia are found. Measured in percentages of volume the nitrogen forms 79 per cent, the oxygen 21 per cent and carbon dioxid .3 of one per cent. In percentage by weight, nitrogen forms 77 per cent and the oxygen 23 per cent. Recent investigations, however, have shown that the percentage of nitrogen just mentioned actually includes a very small percentage of elementary gases previously unknown. The most important of these new elements has been called argon, and measures about .94 of one per cent by volume and 1.3 per cent by weight. These proportions, however, are true only for the lower layers of the atmosphere. Other newly discovered gases of the atmosphere are helium and krypton.

While the percentages of nitrogen and oxygen remain about the same from season to season in the lower levels of the atmosphere, and their distribution continues fairly uniform, the percentage of carbon dioxid is subject to very decided fluctuations, both seasonally and regionally. In general, there is more carbon dioxid present in the atmosphere over the land than over the sea, and somewhat more during the day over the land than during the night. The quantity of carbon dioxid also is subject to a slight but regular decrease as the altitude increases. The chief factors affecting the quantity of carbon dioxid in the atmosphere at the surface are the presence or absence of large bodies of woodland and the proximity of human settlements, especially those characterized by many furnaces or other fires. The composition by volume of the atmosphere at different levels is best shown by the accompanying table:

TABLE SHOWING PERCENTAGE COMPOSITION OF THE ATMOSPHERE AT DIFFERENT LEVELS.

Height in kilometers	0	10	20	50	100
	Per cent	Per cent	Per cent	Per cent	Per cent
Nitrogen	78.04	81.05	85.99	89.62	95.35
Oxygen	20.99	18.35	13.79	10.31	4.65
Argon	0.94	0.58	0.22	0.07	0.00
Carbon dioxid . .	0.03	0.02	0.004	0.00	0.00

The composition of the atmosphere is significant chiefly for two reasons: First, the presence in it of oxygen, diluted by nitrogen, which supports the different forms of life and combustion of fires. Second, the presence or absence of relatively large amounts of carbon dioxid and of water vapor is of great importance in determining the behavior of the atmosphere toward the heat received by the earth or given off from the earth.

The significant physical properties of the atmosphere.

The atmosphere has been found to possess a number of physical properties, some of which it is particularly necessary to understand in studying the laws that control weather and climate. Among the most important of these properties besides those of weight and pressure, are its constant tendency to expand when relieved from pressure, its compressibility when subjected to increased pressure, and its tendency to contract when cooled and to expand when warmed. Especially important is the fact that perfectly dry air permits the heat rays from the sun to pass through it readily, so that these rays warm the solid rock or soil at the surface. In consequence of this property, called diathermancy, the atmosphere is not greatly warmed by the direct action of the sun. Of the radiant energy from the sun that strikes the outer or upper surface of the atmosphere, all the very shortest waves and also other special waves are at once absorbed, so that for a zenithal sun 25 per cent of the heat thus brought to its outer boundary remains in the air. Of the rays that eventually strike the ground the short ones are known as reflected light and have but little heat; the remainder are absorbed at the surface of the ground and warm it. This heated surface sends a small part of its heat downward into the soil, a larger part is lost by conduction to the adjacent layer of air, and a third small part is radiated as long heat waves through the atmosphere into outer space. The layer of air in contact with the ground and warmed by conduction from it rises in consequence of this warming, is replaced by colder air which in turn is warmed and rises, and thus the whole lower atmosphere is gradually warmed by alternating conduction and convection.

On the other hand, the conductivity of the atmosphere for heat is very slight. Expressing this conductivity in small calories, the calorimetric measure of the conductivity would be 0.000053, which is about 20,000 times smaller than that of copper and 3,000 times smaller than that of iron. From this it is plain that the atmosphere must serve as a blanket tending to retain near the surface of the earth the heat which the latter is giving off in the form of radiation.

The transparency of the atmosphere depends directly on the number of foreign particles suspended in it. These are chiefly dust particles, smoke particles and minute particles of water, called mist. These particles produce more or less haze in the atmosphere by what is termed mechanical means, and play an important part in the familiar meteorological phenomena. Since this mechanical haze results from the presence of fine particles, we naturally expect to find the greatest number of impurities collected in the lower levels of the atmosphere. Indeed, it is a fact well known to all those who have had opportunity to compare the air in the valleys with the air over neighboring mountain tops, that the high levels reached in climbing the mountains are composed of clearer, cleaner air than are the low levels confined in the valleys. Indeed, it requires but a slight ascent, of perhaps not more than one mile above the surface of the earth, in order to rise above by far the largest proportion of these mechanical impurities.

SECTION II. THE TEMPERATURE OF THE ATMOSPHERE

The source of heat.

The climatic element that most frequently demands attention is the temperature of the atmosphere. In the preceding paragraphs it has been explained how the atmosphere permits the heat from the sun to pass through it to the earth. In the same way, the heat which the interior of the earth is known to possess, is allowed to pass from the earth outward through the atmosphere into space. But it must not be concluded, because the interior of the earth is very hot, that the temperatures that we feel in the atmosphere are to any considerable degree influenced by the interior heat. There are several conceivable sources of the heat that warms the atmosphere. These are the sun, the moon, the stars and the earth. Of these sources, the greatest amount of heat, as is well known, is received from the sun. So far as the studies of astronomers, geologists and physicists have been able to determine, the only heat that is received from the moon is that which it reflects. The moon seems to have no heat of its own. As regards the amount of heat received from the stars, which are but infinitely distant suns, it needs but a moment's reflection to perceive that their great distance prevents the earth from receiving but an infinitesimal

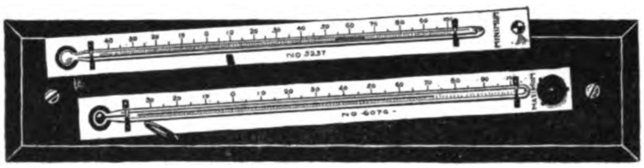


Fig. 709. Minimum and maximum thermometers.

portion of whatever heat may be radiated by them. Concerning the heat that might possibly be received from the interior of the earth, it is well to recall that in spite of volcanic eruptions which show that the earth is still very hot in its interior, the crust of the earth is made up of a series of rocks which are very poor conductors of heat, so that it is an extremely small fraction of its interior heat which escapes to the surface to add to the temperature of the atmosphere in contact with the land surfaces. If the temperature of the atmosphere were in any degree controlled either by the heat escaping from the interior of the earth or by heat radiated from the innumerable stars that surround the earth, it would be difficult to understand why temperatures vary as they do from the equator toward the poles or from season to season. The seasonal changes make it evident that the sun controls the temperatures of the surface of the earth and the temperatures of the atmosphere in contact with it.

The measurement of temperature and solar radiation.

Since the temperature of the atmosphere is thus so directly dependent on the amount of heat radiated from the sun, students of meteorology have long endeavored to find some way of measuring this radiation, and have devised various instruments for that purpose. This radiation is usually called by the special name of insolation, and has been measured in various ways by different types of instruments, all of which are rather complicated and delicate in construction. It has been calculated, however, that the heat received in one minute by a square mile of the surface of the earth when the rays of the sun fall vertically on it would be sufficient to warm 750 tons of water from the freezing point to the boiling point in one minute. The whole amount of heat received from the sun by the earth in one minute has been calculated to be sufficient to raise thirty-seven billion tons of water the same amount. Expressed in another way, the insolation received by the earth in the course of one year would be sufficient to melt a layer of ice covering the whole earth to a depth of 160 feet. Yet the earth, because of its small size, receives only one-two-billionth part of the total amount of heat given out by the sun.

Fig. 710. Richard's thermograph. The curved box, extending from the right of the case, is connected to the long pen-arm. Changes in temperature cause the curved box to straighten, the extent of this movement being recorded by the pen-arm on the drum.

In order to measure the temperatures and changes in temperature which this insolation produces in the atmosphere, the instruments called thermometers have been invented; while to measure the duration of sunny weather, or, as it is usually called, the amount of sunshine received by any place, an instrument known as a sunshine recorder has been devised. Different types of thermometers are shown in Figs. 709 and 710. The familiar form of thermometer, similar to those in Fig. 709, consists of a closed tube with a bulb filled with mercury or alcohol at one end, opening into a very fine tube running through the long stem of the thermometer from which all air has been excluded. As the heat increases or decreases, a corresponding increase or decrease of volume of the material filling the thermometer bulb causes the thin column in the bore to rise or fall. Ordinary thermometers have a scale divided on their stem or attached to it, and require that one shall read off the position of the column of liquid whenever he wishes to know what is the temperature of the air. A more convenient form of thermometer is shown in Fig. 710, since this instrument draws on a strip of paper a line which rises or falls according as the temperature increases or decreases. It is called a thermograph. It consists essentially of a curved metallic box shown projecting beyond the case to the right. To this box is attached, by means of a set of levers, the long pen arm that is shown behind the glass tracing a rising line on the cylinder of paper. Changes in temperature of the gas contained in the curved box cause it to straighten more or less, and consequently to move the long pen arm up or down across the paper. The strip of graduated paper is wrapped around a drum, which is driven by clock-work and usually completes one revolution in seven days. The record written on this strip of paper by the pen attached to the long lever is thus made continuously for a long time without requiring any attention from the observer, and thus furnishes valuable continuous records of the time of the changes in temperature with the least expenditure of human energy. Unfortunately, the instrument is subject to various errors which do not enter into records obtained by reading off temperatures from a carefully constructed thermometer of the usual type.

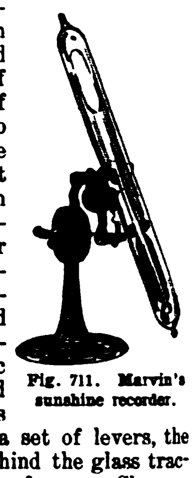


Fig. 711. Marvin's sunshine recorder.

Nevertheless, such records are of great value in studying continuous temperature changes, especially in localities difficult to reach or quite inaccessible.

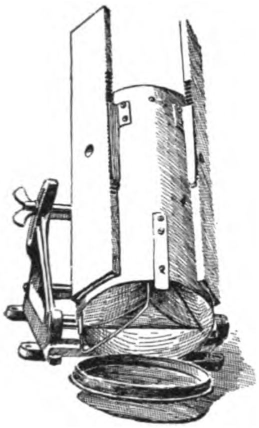


Fig. 712. Jordan's sunshine recorder.

Among those temperatures which have especial interest are the maximum and minimum temperatures reached day by day at the different observing stations. Such temperatures are likely to be missed by an observer, even when he reads an exposed thermometer every hour; to overcome this, a pair of thermometers such as those shown in Fig. 709, has been invented. This pair consists of a mercurial thermometer, shown in the lower part of the figure, so constructed that the mercury can flow freely from the bulb into the stem as it expands, but is unable to draw back as the temperature falls. This thermometer is set once a day and then left undisturbed, and will record automatically the maximum temperature reached since it was last set. The upper thermometer of the pair represented is filled with alcohol instead of mercury, and contains in the stem a small black pin called an index. If the thermometer be tipped upside down, the index runs down the stem until it reaches the top of the alcohol column, where it stops. When the thermometer is brought to a horizontal position again, as shown in the picture, the index remains at rest at the top of the alcohol column and does not move forward as the liquid flows past in expanding. When the temperature begins to fall and the liquid contracts into the bulb, the top of the column soon begins to drag down the index, and it finally leaves the index pointing to the lowest temperature reached by the thermometer since it was last set. Such a pair of thermometers, if properly exposed, are very useful in indicating the daily extreme temperatures reached by the lower atmosphere.

A word should be said about the proper exposure of instruments for recording the atmospheric temperatures. Care must be taken that the thermometers are not in the direct sunlight and that they are sufficiently removed from any reflecting or radiating surface, like the wall of a house, so that they do not indicate temperatures controlled by such objects. The best way to expose them is to hang them under a shed that is open on all four sides, but has a sufficiently extended roof to keep the thermometers always in the shade and to protect them from the rain. In order to avoid wetting thermometer bulbs by rain or snow, the instruments are usually exposed in a shelter whose sides are closed in by slats and provided with a double roof. (See Figs. 701 and 730).

The horizontal distribution of temperature.

In studying the distribution of temperature by means of thermometers, it is found that the amount of heat received by any place is primarily dependent on the angle at which the rays of the sun strike the surface of the earth, as is shown in Fig. 713.

If a ray of heat of unit cross-section strikes the earth vertically, all the heat brought by it to the earth is concentrated on the smallest possible area. According as this unit ray reaches the earth more and more obliquely, the unit amount of heat must be spread over rapidly increasing areas, so that when the ray falls most obliquely it has to distribute its heat over the largest surface; therefore, any given point on the surface of the earth receives the most heat when the rays of the sun strike most nearly vertically. It is a familiar fact that the sun is most nearly overhead at noon day by day, and in midsummer from season to season,

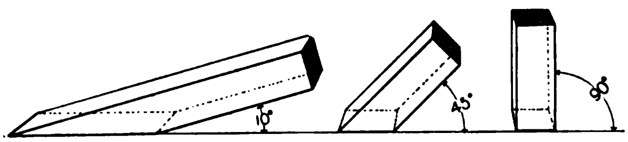


Fig. 713. Showing the varying intensity of insolation received under different angles of incidence of the sun's rays.

consequently we expect to find that these are the times of the day and of the year when any given place is receiving the greatest amount of insolation. This relation between the obliquity of the rays of the sun and the amount of insolation received by the earth is further brought out by the accompanying table, which shows the relative amount of insolation received in a single day and at different times of the year by points lying along different parallels:

Relative Amounts of Insolation Received in One Day at Surface of the Earth.

Latitude	0°	+20°	+40°	+60°	N. Pole	S. Pole
March 21 . . .	1.000	0.934	0.763	0.499	0.000	0.000
June 21	0.881	1.040	1.103	1.090	1.202	0.000
September 22 . .	0.984	0.938	0.760	0.499	0.000	0.000
December 21 . .	0.942	0.679	0.352	0.000	0.000	1.284
Year	347.0	329.0	274.0	197.0	143.0	143.0

This table shows, in addition, that for most seasons in the year the poles receive almost no insolation, while the equator or the tropics receives the maximum amount. In fact, this is the average condition, as is shown by accompanying maps, which present the average temperatures observed at many widely scattered points over the surface of the earth. The map (Fig. 714) showing the average annual distribution of temperature, consists of a set of curved and waving lines drawn across the lands and seas of the globe. Each of these lines represents the average annual temperature of all the points on the surface of the earth through which it passes, and all the points lying on any line are therefore supposed to have the same average temperature. These lines are called isothermal lines, or, briefly, isotherms. A study of the broad features of the map shows that there extends around the globe a belt of maximum temperatures whose boundaries run, in general, parallel two places to lie somewhat south of it. The cause of this shifting in position of the thermal equator is not far to seek, if we recall the general law that the earth receives the maximum amount of insolation in those regions where the rays of the sun strike it most nearly vertically. In July we know that, owing to the oblique position of the axis of the earth with reference to the plane of its orbit, the rays of the sun fall more nearly vertically over the southern part of the northern hemisphere than they do over the southern hemisphere. Consequently the zone of maximum insolaton lies north of the geographical equator, as is also shown in the table given on page 555. Following this zone of maximum insolation we find the zone of maximum temperatures of the thermal

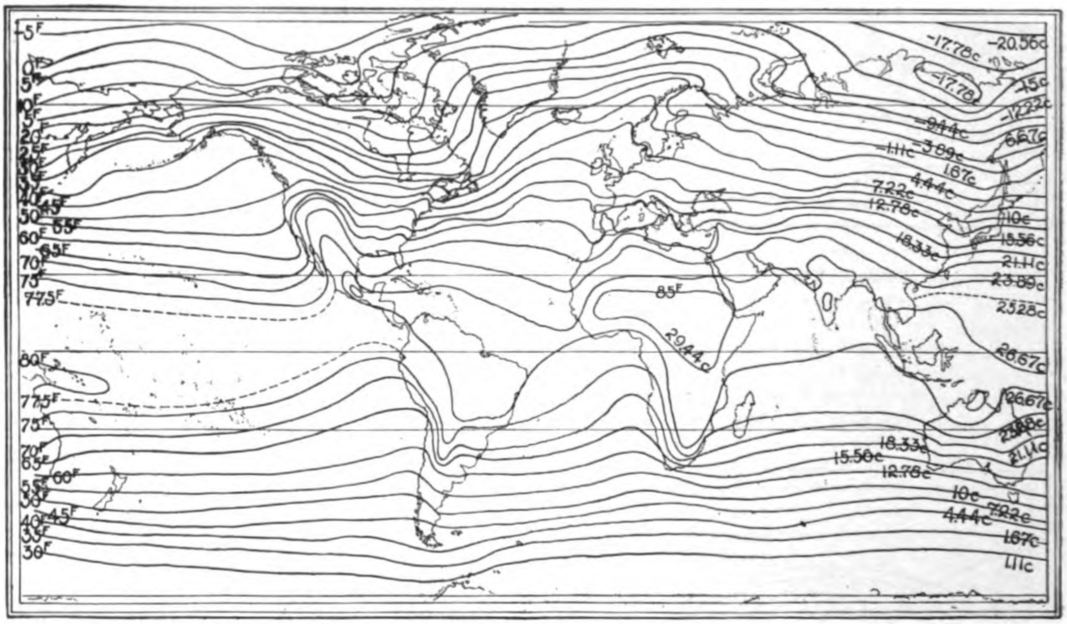


Fig. 714. Mean annual temperature. World isotherms. (After Bartholomew.)

with the equator, and that on either side of this belt the average temperature decreases more or less regularly toward either pole. The axis of the belt of high temperature is known generally as the thermal equator, and will be found to lie north of the geographical equator throughout the greater part of its course. This is, indeed, the average temperature condition of the globe for the year. But on comparing the chart of annual isotherms with the two small charts, showing the positions of the isotherms in January and July respectively (Figs. 715 and 716), it appears that the thermal equator shifts its position from season to season. In July it is found to lie farther north of the equator, and the actual temperatures inclosed in the zone of maximum temperature are considerably higher than are those temperatures which characterize the same zone in January. In January, also, the thermal equator is found to lie much closer to the geographical equator, and in one or

equator lying farther to the north. On the other hand, in January the northern part of the southern hemisphere receives the maximum amount of insolation, and consequently the zone of maximum temperature is shifted to the position shown in the chart of January temperatures.

The question now arises, Why do these lines of equal temperature or isotherms have such irregular courses, and why does the thermal equator move further to the north of the geographical equator in July than it moves to the south of the geographical equator in January? If the temperatures of points on the surface of the earth depended solely on the angle at which the rays of the sun strike the earth, all those points lying on the same parallel of latitude might be expected to have the same temperature at a given season of the year, for the inclination of the rays of the sun decreases regularly parallel by parallel from the equator to the poles. The irregular courses of the seasonal and annual

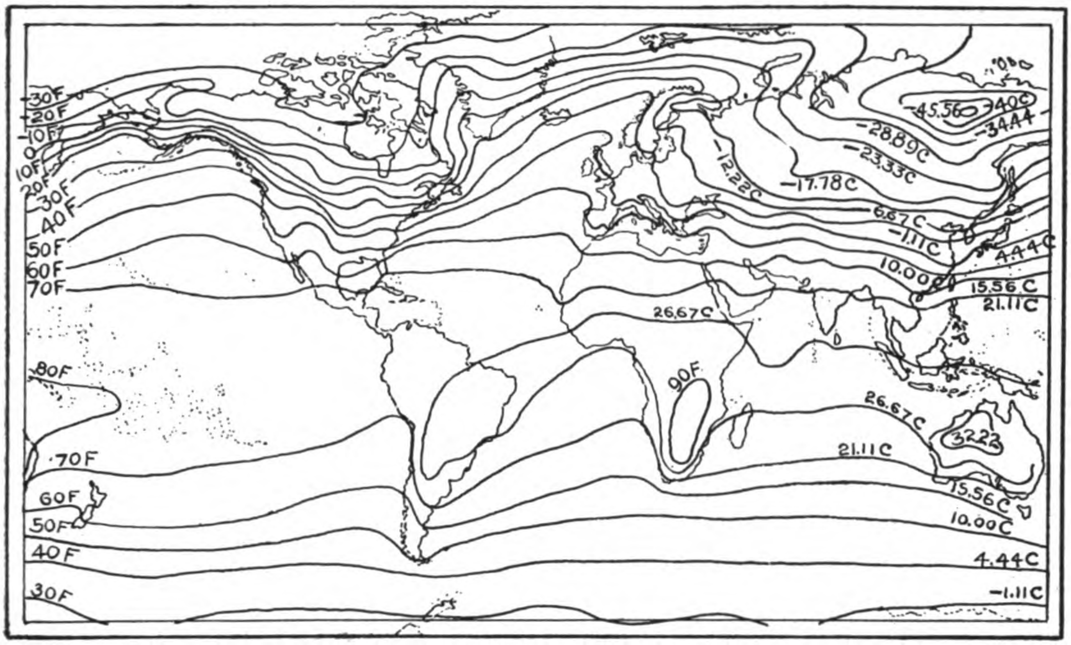


Fig. 715. World isotherms for January. (After Bartholomew.)

isotherms must rest on some other basis than solely that of variations in the amount of insolation received.

As we study these isothermal lines more closely, it becomes evident that the irregularity in their courses results in part from the fact that they lie more closely together over the lands and farther apart over the oceans, and this particular feature of the maps showing the average distribution of temperature over the world may be explained in the following way: It is a well-known property of water that it requires a relatively large amount of heat to raise a given volume 1° Fahr. in temperature, while other substances, such as rock and soil,

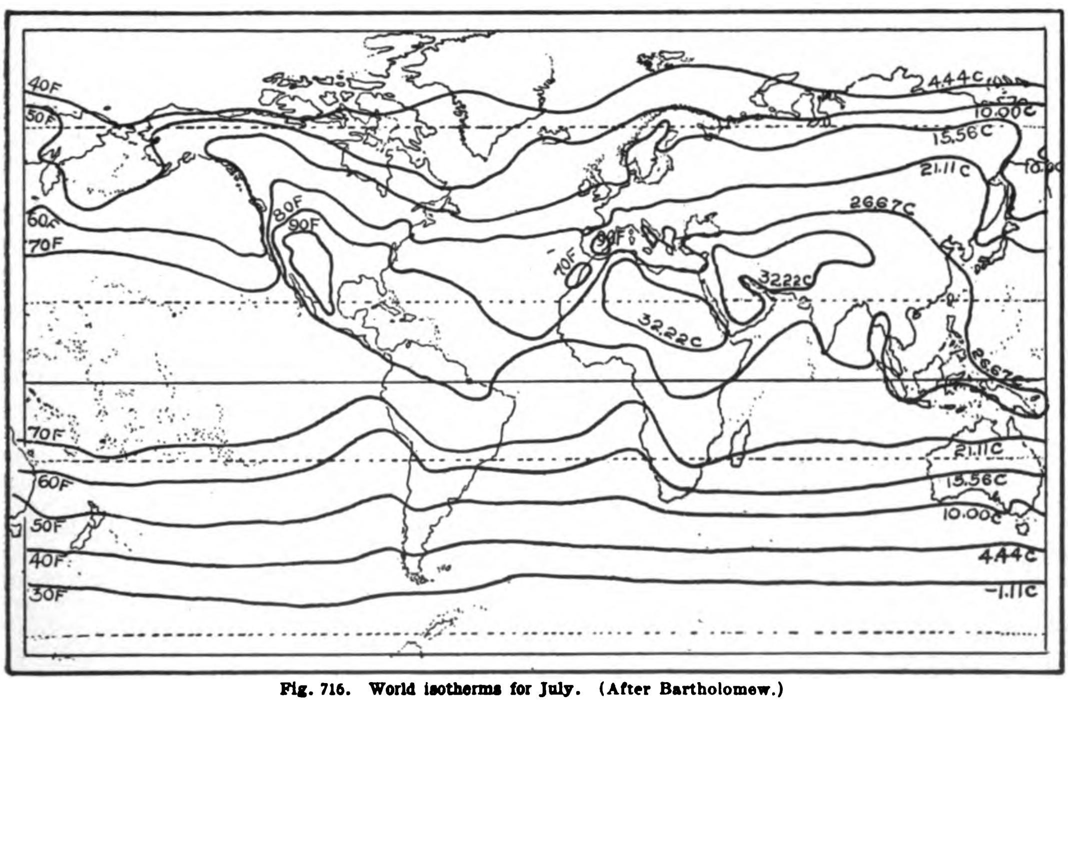


Fig. 716. World isotherms for July. (After Bartholomew.)

require much less heat to raise their temperatures through the same amount. On the other hand, it has been found to be the case that substances like water, whose temperatures are raised very slowly through the accession of heat, also cool very slowly by radiation of the heat they have received, while substances like rock and soil cool very rapidly by radiation; consequently, the air lying next to the surface of the ocean warms very slowly during the day and during the summer, and cools equally slowly during the night and during the winter. The air resting on the continents, on the other hand, warms rapidly during the day and during the summer months, but cools almost as rapidly during the night and during the winter. The isothermal maps for January (Fig. 715) and July (Fig. 716) bring out this contrasted influence of land and sea very clearly. In July the isotherms show lower temperatures over the ocean than prevail over the lands in the same latitude, while in January we find higher temperatures over the ocean than over the corresponding land masses. The average for the year shows generally lower temperatures over the land and higher temperatures over the oceans, due to the fact that the oceans are slowly giving out heat throughout most of the winter. During that season their temperatures are falling very slowly and the air in contact with their surfaces is kept slightly warmer, while the temperature of the lands falls much more rapidly in the winter, quite counterbalancing the higher temperatures prevailing over them in the summer.

There is, however, another important factor that helps to maintain more uniform temperatures over the ocean surfaces throughout the year than over the land surfaces, and this is the constant interchange of water between the equator and the poles which is brought about by the ocean currents. These ocean currents form general drifts from the equator toward either pole along the eastern coasts of the great continental masses, while the western coasts of the continental plateaus are generally followed by currents flowing from higher to lower latitudes. The causes of these currents, which are wholly surficial phenomena of the ocean, will be discussed later. At present it is sufficient to know that they furnish a constant contribution of cold water from the poles to the tropical belt, and of warm water from the tropics to the poles. The very strong northeastward deflection of the isotherm of 32° Fahr. over the Atlantic is due in part to the drift of warm water from the tropical Atlantic toward the northeast. In a similar way, the strong northward deflection of the isotherm 68° Fahr. along the western coast of South America is due in large part to the deflection of a stream of cold water from the Antarctic ocean into the tropical Pacific by the southward extension of the South American continent. Similar deflections of isotherms are found along the western coast of Africa and the coasts of California and Lower California.

Range in temperature.

The maps of seasonal isotherms suggest another very important feature of the relative changes in temperature over land and sea. The two maps, Figs. 715 and 716, show that the region of lowest January temperature, situated in Siberia, is characterized by such extremely low temperatures in that month, and by such high temperatures in July, that the entire region experiences an extreme change of temperature from winter to summer. The entire region is characterized by a great annual range of temperature; indeed, it is the region of maximum annual range of temperature. Comparisons of the average temperatures for January and July of the other continents show that the winters of each of the remaining four great land divisions are also characterized by very marked annual ranges of temperature. On the other hand, the same maps show that the contrast between the summer and the winter temperatures over the oceans are far less strongly marked; indeed, that part of the watery envelope that lies approximately between the tropic of cancer and the tropic of capricorn shows the least annual range of any region of the globe. All of the small islands lying within this zone of minimum annual range of temperature are likewise characterized by very slight temperature changes due to the preponderating influence of the surrounding ocean. In fact, if we had a map showing lines of equal annual range of temperature, we should find that all the coastal regions of the world are subject to much smaller annual ranges of temperature than are the interiors of the continents. In other words, the annual range of temperature increases rapidly from the coast toward the interior of any considerable land mass.

The regular changes in temperature from month to month for points variously located with reference to the center of a continent or ocean, are shown in the set of temperature curves forming Fig. 717. The well-known daily change in temperature is also shown in the upper curve of Fig. 720, the daily temperature range for several days here being expressed by the changing width of the band bounded by dotted lines.

In general, we need to remember, from the study of the isothermal charts, that temperatures over the land areas rise higher in summer than do the temperatures over the oceans; that the lowest temperatures of winter are found over the land and the highest over the water; and, most important of all, that a shifting zone of maximum temperature runs somewhat irregularly around the earth, with its axis usually a little north of the equator. On these peculiarities in the general distribution of temperature depend most of the other important phenomena of meteorology and climatology.

Vertical distribution of temperature.

In the preceding discussion, the horizontal distribution of temperature and the chief changes which it shows have been considered. The temperature of the atmosphere, as might be expected, also changes with the altitude of the point of insolation. It was early discovered that the average daily temperatures of places located on tops of high mountains were decidedly lower than those at the base of the same mountains. The results of many measurements of these differences in temperature due to difference in altitude have shown that, on the average, the temperature decreases at the rate of 1° Fahr. for every 300 feet of elevation, at least in the lower layers of the atmosphere. This decrease in temperature appears to be in direct contradiction to a law which says that the amount of heat received from any radiating body varies inversely with the distance from that body. In the case of the temperatures on the earth, however, we must remember that as we ascend into higher and higher levels of the atmosphere, the latter becomes thinner and thinner, so that although high-lying objects, such as mountain peaks, receive more intense insolation from the sun, at the same time they are able to radiate heat more rapidly. Since the temperature of any body represents the difference between the amount of heat received and the amount of heat radiated by it, it is clear that, as radiation increases, the temperature of the body falls. Furthermore, the rare and relatively very pure atmosphere at great altitudes is incapable of becoming so highly heated by insolation as the lower, denser and dustier layers.

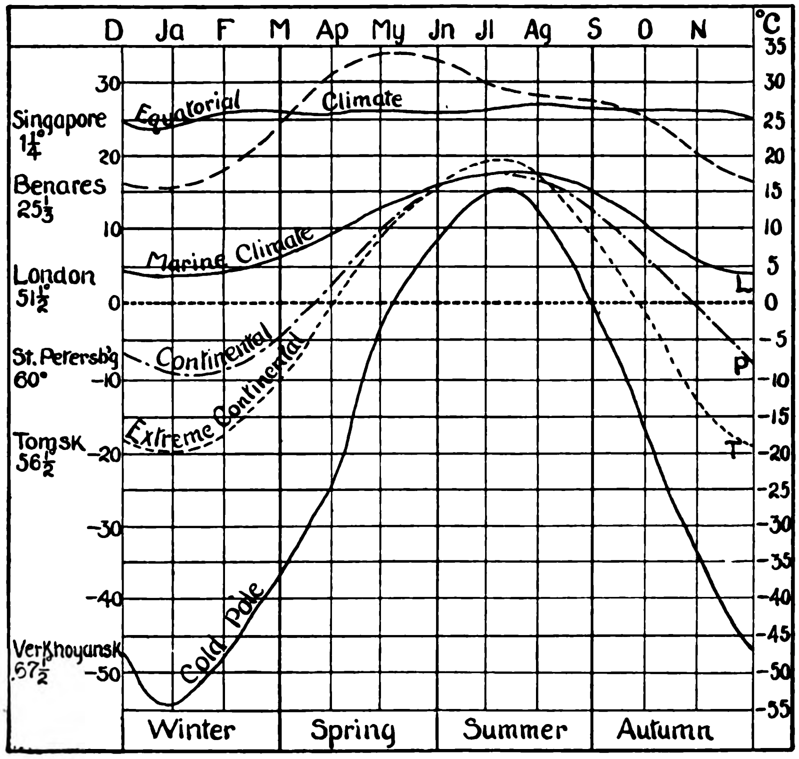


Fig. 717. **Typical annual temperature curves of different climates.** (After Wagner.)

long as no disturbing influences in the shape of clouds and winds intervene.

The average rate of temperature decrease with increasing altitude is subject to two periodic changes,—one daily, the other yearly. The daily change results from the warming in the day, and the more rapid cooling in the night, of the lower layers that are in contact with the ground. The accompanying table shows decrease per 100 meters in a rather mountainous region. (A meter is 39.37 inches):

Daily Variations in the Rate of Vertical Temperature Decrease Between Kolm Saigurn (1600 meters), and the Sonnblickgipfel (3106 meters). [In degrees Centigrade per 100 meters.]

	Mid-night	2 a	4 a	6 a	8 a	10 a	Noon	2 p	4 p	6 p	8 p	10 p	Mean
Winter	0.50	0.49	0.49	0.49	0.50	0.60	0.66	0.59	0.54	0.52	0.51	0.50	0.53
Summer	0.64	0.62	0.60	0.69	0.81	0.87	0.89	0.88	0.82	0.73	0.68	0.65	0.74
Year	0.56	0.55	0.54	0.57	0.65	0.74	0.79	0.75	0.68	0.61	0.58	0.57	0.63

The range in temperature of the lower, denser layers of the atmosphere would normally be greater than the range in temperature of the higher layers. The extent of the daily and annual temperature ranges of the atmosphere will be influenced by the conditions prevailing over the surface of the earth if the air is in contact with it; but, even thus modified, the general relation between the ranges in the upper and lower layers remains that just stated so

Where the topography is of a mild character, as over plains or plateaus, this daily variation in the vertical temperature decrease may even go so far as to produce what are known as inversions of temperature. In the latter case, we can observe an increase in temperature with increase in altitude due to the very rapid cooling of the lower layers in contact with the rapidly cooling surface of the ground. In general, the maximum rate of vertical temperature decrease is found about midday and the minimum just before sunrise.

Corresponding to the daily period of this vertical decrease of temperature, occurs a yearly period resulting from the change from winter to summer conditions of insolation. In temperate latitudes the slowest rate of vertical temperature decrease occurs in the winter and the most rapid in the early summer. The accompanying set of calculations for Pike's Peak shows the change in vertical temperature decrease per 100 meters through the year:

Vertical Decrease in Temperature (°C) Per 100 Meters, Between Pike's Peak, Colo., (4308 meters), and Colorado Springs, Colo., (1859m).

Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
0.54	0.59	0.67	0.73	0.74	0.72	0.68	0.65	0.62	0.59	0.55	0.53	0.64

One of the most generally interesting features connected with the vertical decrease in temperature is the position of the isothermal surface of 0°C. (32° F.), and its seasonal changes in elevation, as shown in the accompanying table:

Altitude (in Meters) of Isotherm of 0° Centigrade in Different Latitudes.

	Andes of Quito	N. W. Himalaya	Etna	Pike's Peak, Colo.	Pic du Midi	E'n. Alps, Tauern	Ben Nevis, Scotland
Latitude	0°	N. 32°	N. 37.7°	N. 38.6°	N. 42.9°	N. 47°	N. 56.8°
January	5,100	2,800	1,900	1,150	1,350	0,000	640
July	5,100	5,700	3,980	4,970	3,940	3,300	2,000
Year	5,100	4,700	2,950	3,200	2,480	2,050	1,250

Naturally it is found that this temperature surface preserves the most uniform height at the equator and is subject to its greatest fluctuations in the mountain regions located in the interior of the continents.

Section III. The Pressure and Circulation of the Atmosphere

The sensations that we daily experience, so far as they relate to the atmosphere, are confined to changes in the temperature, changes in moisture, and the movements of the atmosphere which we call the winds. We are unconscious of the fact that this mobile gas is everywhere pressing on us and on all the objects about us; but if we place our hand over the orifice of a tube leading to the air-pump and then remove the air from beneath the hand, we soon realize that some invisible substance is pressing very heavily on it. Again, if we ascend in a balloon or climb a mountain of considerable elevation we experience sensations which suggest to us, almost without conscious effort of thought, that the pressure on the external surface of our bodies has been reduced. Thus we have come to accept almost as a truism the fact that our gaseous atmosphere is pressing on the earth and normal to the surfaces of all objects both at its surface and at considerable elevations.

The importance of this atmospheric pressure is not always clear. We know that in any large vessel partly full of water the surface of the water forms what we call a horizontal plane, and we all learn by experience that we cannot make the surface of the water higher in one part of the vessel than it is in another. This peculiarity is due to the fact that the liquid moves over itself very easily, so that the unequal pressure caused by any attempt to heap up the water at one end of the vessel higher than at the other causes the lower strata of water to slip from under the extra load, and to flow toward the point of reduced pressure. The atmosphere, being a gas, is much more mobile than even the easily-flowing water, and it is at once evident that whenever the atmosphere is in motion, producing what we call winds, it must be moving under the influence of two or more regions of unequal pressure. The air is pushed from a region of higher pressure toward a region of lower pressure. Hence, if we wish to know anything about the source and the destination of the wind, or all the peculiar conditions under which the different classes of winds originate, we must carefully measure the pressure of the atmosphere at many different points over the surface of the earth.

The measurement of atmospheric pressure.

We may measure the pressure of the atmosphere either by measuring the change in the height of a column of liquid supported only by that pressure, or by measuring the condensation and expansion which the varying pressure of the atmosphere induces in a delicately constructed box from which the air has been exhausted as perfectly as possible. The water raised by a small pump rises in the barrel of the pump because the pump piston relieves the surface of the water in the barrel from the pressure of the atmosphere above it, thus enabling the atmosphere pressing down on the water all around the pump to force a column of water up the barrel. The average pressure of the atmosphere is able to support a column of water 32 feet in height, and any increase or decrease in the atmospheric pressure causes a corresponding rise or fall in this column of water, so that a column of water might be used to measure the changing pressures. Owing to the awkward size of an instrument using water for this purpose, advantage has been taken of the much greater density of the liquid metal mercury, and by substituting it for water, a pressure-measuring instrument of much more convenient size has been constructed. Instead of using a pump-barrel and piston, however, a strong glass tube about 33 inches long, closed at one end, having a bore as uniform as possible, is carefully filled with clean mercury, so that all bubbles of air are excluded from the tube. When the tube, hanging with its closed end downward, is absolutely full of mercury, the open end is temporarily closed, the tube inverted and the open end then submerged beneath the level of some mercury contained in an open cup or cistern. Keeping the open end of the tube below the surface of the mercury in the cistern, the temporary stopper is removed. Immediately the mercury column in the tube falls a short distance, leaving an empty space between the top of the mercury and the closed end of the tube. Evidently this empty space must be a vacuum if the tube has been filled carefully with the mercury; and if it is a vacuum, then the top of the mercurial column is under no significant pressure, for it is relieved from the pressure of the atmosphere by the arch of glass over it. Since the atmosphere cannot now press on the top of the mercury column in the tube, but is still free to press on the surface of the mercury in the cistern, the atmosphere now supports in the tube a column of mercury whose weight is just equal to the pressure of the atmosphere on an equal surface of mercury in the cistern. If the atmospheric pressure increases, then the column of mercury in the closed tube will rise; if the atmospheric pressure decreases, the column of mercury in the tube will fall. Thus the atmospheric pressure may be measured by the height of the mercury in this closed tube.

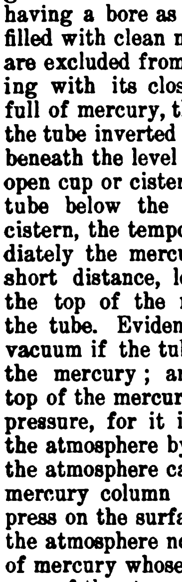


Fig. 718. Mercurial barometers of the cistern type.

For convenience in comparing changes in the height of the mercury column, an adjustable scale in one form or another is attached to the long tube, and the scale may be divided into English inches and tenths of inches or into French centimeters and millimeters. Such an instrument is known as a mercurial barometer (Fig. 718), and, when carefully and accurately constructed, is accepted as the standard instrument for measuring the pressure of the atmosphere. Although such barometers have been constructed in a way to be self-recording, they generally require the presence of an observer, who must read off as correctly as he can the length of the mercurial column. Owing to the necessary length of the instrument and the somewhat fragile character of the glass tube, it is not always a convenient apparatus to carry about from place to place. Besides these drawbacks, it must be corrected for changes in latitude, since the weight of the mercury changes in common with the weight of all other substances with a change of position in latitude. Corrections must also be applied to it for capillarity, for changes in the temperature of the mercury and for the expansive force of a certain amount of mercury vapor always present in the vacuum.

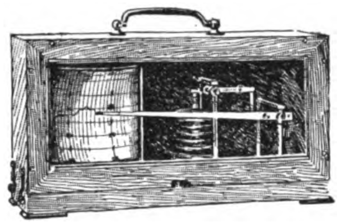


Fig. 719. Richard's barograph, for making continuous automatic records of pressure.

Endeavors to construct a more portable instrument for measuring changes in atmosphere, and one that will yield continuous automatic records of such changes, have resulted in the construction of an instrument called an aneroid barometer. This instrument consists essentially of a corrugated metal box from which the air has been exhausted and which is prevented from collapsing by the pressure of a strong spring. Changes in the pressure of the atmosphere on this box tend to compress it or to allow the spring to expand it, and by connecting the long pen-carrying lever with the box we are able to register the expansion or contraction of the spring on a strip of slowly moving paper. Such an instrument, shown in Fig. 719, is called a barograph, because it is arranged to make continuous automatic records of pressure. A smaller and more portable instrument constructed on the same principle causes a fine steel pointer to move over a circular graduated dial, and is called a pocket-aneroid. This type of barometer is subject to many mechanical errors which have never been completely overcome. Each instrument must therefore be frequently compared carefully with a standard mercurial barometer, in order to determine the corrections necessary for it. In spite of these drawbacks, however, the great advantage it possesses, due to its portable form and to the self-recording feature, have led to its wide adoption for certain lines of work. The lower curves of Figs. 720, 721 and 722 illustrate the character of the record kept by the barograph, and at the same time emphasize the convenience and value of such records in studying consecutive changes in the atmospheric pressure.

Distribution of pressure.

By means of the mercurial barometer the pressure of the atmosphere has been measured at many different points over the earth's surface, some of them near sea-level, others on high mountain tops; and the results of these measurements have been to show that the pressure of the atmosphere is constantly changing everywhere, in some places more rapidly and others less rapidly.

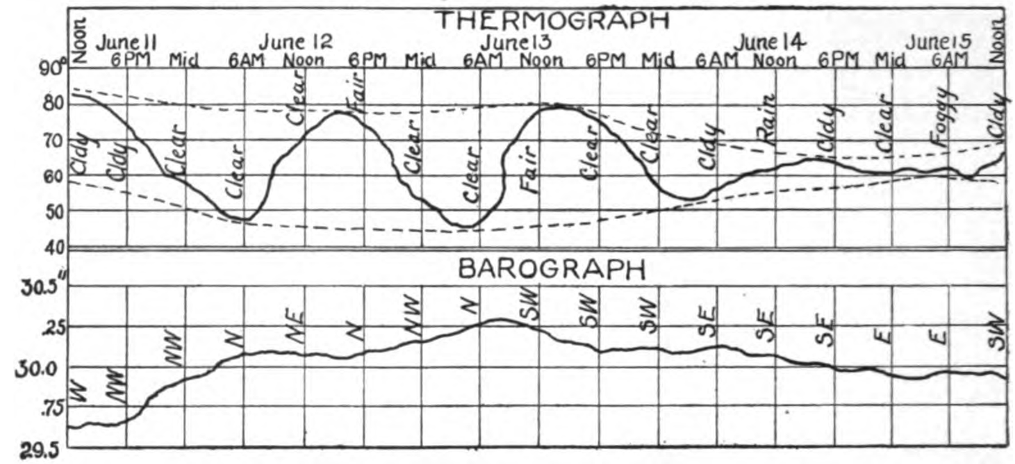


Fig. 720. Normal diurnal curves of temperature and pressure. (After Ward.)

In spite of these irregular changes in pressure, it has been found that the pressure always shows a decrease as we move from lower to greater elevations.

Vertical decrease in pressure.—It has been found that, just as in a body of water the pressure decreases from the bottom layers to the top, the pressure of the atmosphere decreases steadily as we ascend to greater elevations. The change in pressure in the case of the atmosphere, however, goes on at a different rate from the change in pressure with change in depth in a body of water. In the latter case the pressure decreases at a constant rate, while in the case of the atmosphere the pressure decreases less and less rapidly as we ascend. This is due to the fact that the gaseous atmosphere is highly elastic and is much denser in its lower levels than near its outer limit. The rate at which the atmospheric pressure decreases with altitude for an average condition of the air is given in the accompanying table:

ALTITUDE. (Feet)	PRESSURE. (Inches of Mercury)
0	30
910	29
1,850	28
2,820	27
3,820	26
4,850	25
5,910	24
7,010	23
8,150	22
9,330	21
10,550	20
13,171	18
16,000	16

This table shows a rapid increase in the intervals between adjoining barometric levels. An effort is made to illustrate this fact in Fig. 707, which shows the thickness of the earth's surface in relation to the radius of the earth and to the altitude of the highest known mountain ranges. In Fig. 707 the parallel concentric circles are crowded close together at the earth's surface, but spread farther and farther apart as their distance from the earth's center increases. These circles represent, diagrammatically, spherical surfaces in the earth's atmosphere, all the points in each surface being under the same atmospheric pressure. In other words, they represent surfaces of equal pressure, or isobaric surfaces. These surfaces play a most important part in the mechanical production of winds and storms. When the earth's atmosphere is completely at rest and uninfluenced by any other force than that of gravity, these surfaces envelop the earth in a series of shells that are approximately

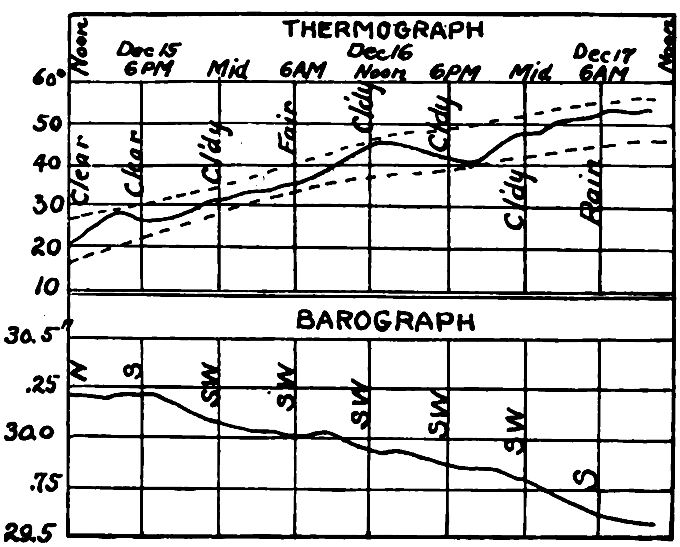


Fig. 721. Cyclonic control of winter temperatures. (After Ward.)

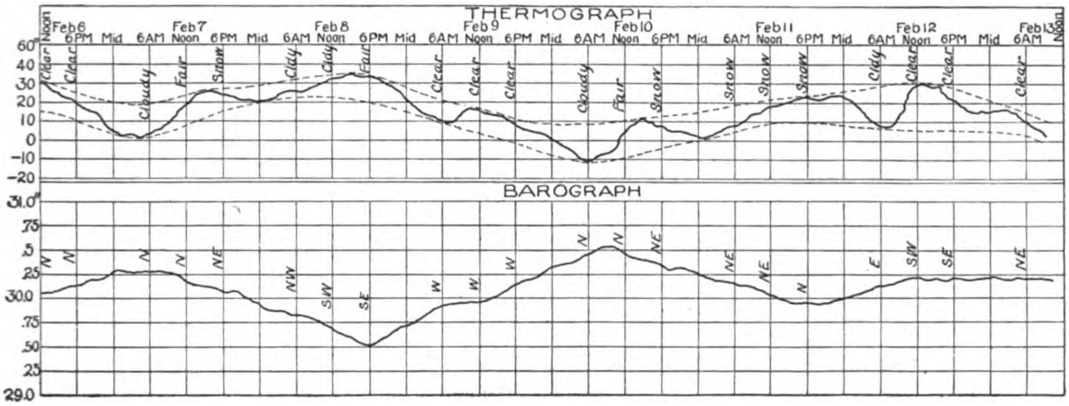


Fig. 722. Thermograph and barograph curves for a week in winter, illustrating strong ranges in pressure and temperature of winter. (After Ward.)

parallel to the general figure of the earth. They will never be quite parallel, however, because the mobile atmosphere tends to be flattened about the poles a little more than the earth is, and to bulge over the equator somewhat more strongly than does the earth. We shall soon see, however, that this ideal condition of an atmospheric envelope at rest is never attained.

Horizontal distribution.—When the observations of atmospheric pressure are plotted on a map of the globe, it is seen that the pressure is not equal over every part of the lands or of the seas, but that some regions have higher pressure than do others. A study of small areas only shows that the pressure is constantly changing. If the attention is confined for a moment to the broad features of distribution of pressure, it is found that here, as before, is needed some means for presenting graphically the conditions over great areas. One may draw lines connecting all those points that have the same atmospheric pressure, and these lines fall irregularly but in defined paths. Such lines are called isobaric lines or isobars, this word indicating that these lines represent lines of equal pressure on the earth's surface. It has already been seen that, even under the most ideal conditions of the atmosphere, pressure decreases with increased altitude, even if the pressure at sea-level remains the same over a large area. From this it is evident that when comparing the actual positions of the isobaric surfaces in the atmosphere we must not compare the atmospheric pressures as they are actually measured at the different points of observation, but we must add to or subtract from the individual observations such quantities as will serve to express the atmospheric pressure at a definite and uniform level. The plane of reference that is usually used for making this

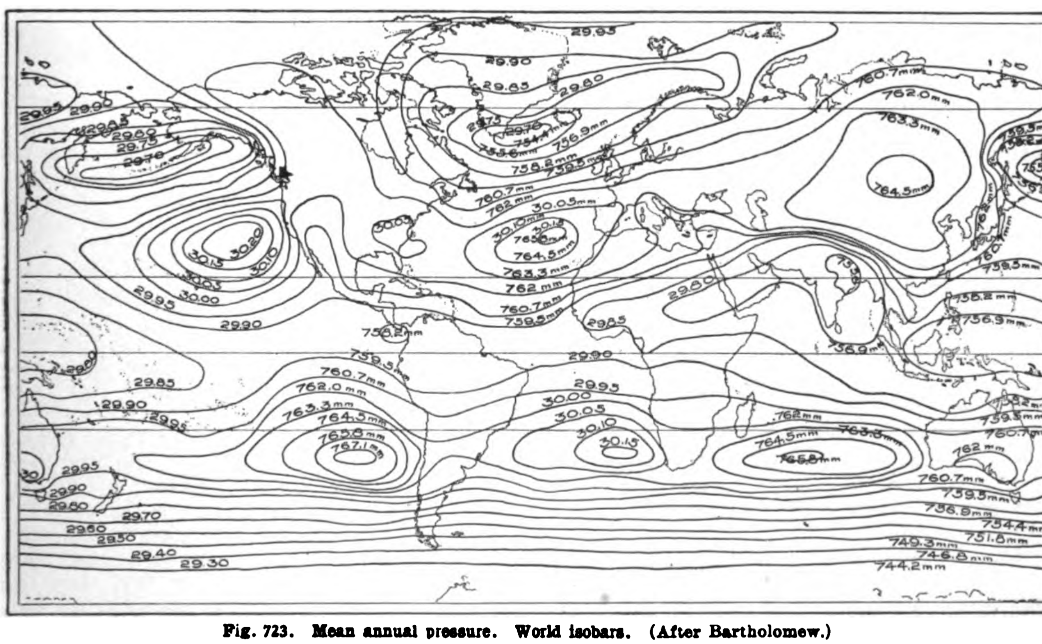


Fig. 723. Mean annual pressure. World isobars. (After Bartholomew.)

reduction is that known as mean sea-level, although it would be somewhat more logical to employ a plane of reference lying sufficiently far above sea-level so that its surface would escape all the major inequalities of the earth's surface. Having made these reductions of the observed pressure, the resultant values may be entered on a map such as is given in Fig. 723, which shows the average annual pressure of the atmosphere reduced to sea-level. (Bartholomew's Physical Atlas, London.)

This chart of annual isobars brings out the fact that there is a zone or belt of relatively low pressure encircling the world between the tropics, while to the north and south of this tropical belt of low pressure lie two rather narrow belts of relatively high pressure which encircle a center of low pressure in the vicinity of either pole. In order to bring out yet more vividly what this chart shows, Fig. 724 has been drawn. This figure presents a cross-section of the isobaric surfaces in the earth's atmosphere from one pole to the other. It brings out distinctly the fact that over the equator the isobaric surfaces sag downward, forming a trough of low pressure lying between two arches of high pressure over either tropic. The figure further shows very distinctly that the decrease in pressure from the tropics to the poles is much more rapid in the southern hemisphere than in the northern, a fact expressed in Fig. 723 by the closer crowding together of the isotherms over the Antarctic ocean.

Fig. 724, however, shows other features that naturally could not be represented on the chart, since the latter represents only the pressure conditions at sea-level. Reference is here made to the relative positions of the isobaric surfaces lying higher than sea-level. These are shown in the illustration as gradually changing from an equatorial sag in the lower levels to a great arch in the uppermost levels. Reference will be made later to this peculiar vertical distribution of pressure along the meridians, and here the study of the horizontal distribution at sea-level will be continued.

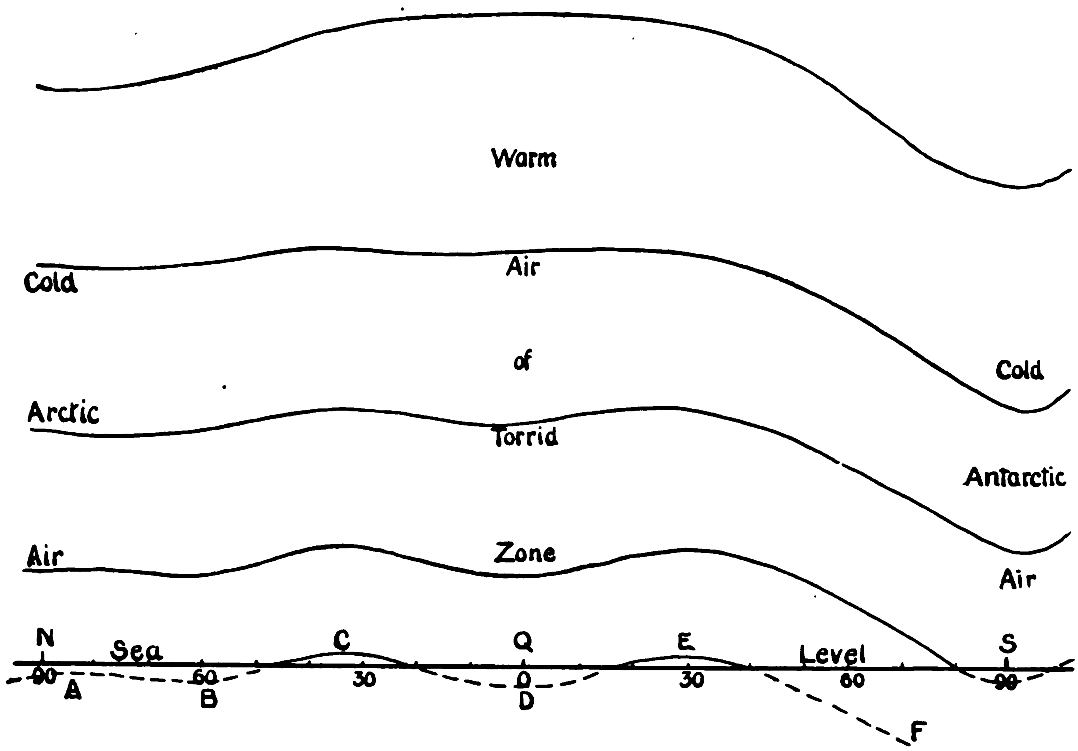


Fig. 724. A vertical section of the earth's atmosphere along a meridian. Over the equator the isobaric surfaces sag, forming a trough of low pressure lying between two arches of high pressure over the tropics. Note also that the decrease in pressure from the tropics to the poles is much more rapid in the southern hemisphere than in the northern.

Proceeding to a closer study of the distribution of pressure over the globe, the chart (Fig. 723) shows that there are broad areas of unusually high pressure located in the belts of generally high pressure and neighboring centers of markedly low pressures included in the belts of low pressure. The zone of low pressure surrounding the Antarctic ocean, however, seems to present no special centers of low pressure, but to have a regular and rapid decrease toward high antarctic latitudes.

Recalling what has been said as to the relation between the centers of high and low pressure in a liquid and of the direction of currents in that liquid, this map of annual isobars prepares us for the idea that the atmosphere of the whole globe must be moving. At the surface of the ocean it must move toward the equator from the equatorward sides of the tropical high pressure belts, and toward the poles from the poleward sides of the same belts. The relation between these movements of the atmosphere and the distribution of pressure over the globe is somewhat more clearly brought out in Figs. 733 and 726, which show the distribution of pressure and winds for the Atlantic ocean in July. Here is seen everywhere a general movement of the lower layers of the atmosphere toward belts or centers of low pressure and away from belts and centers of high pressure. The reason for this movement may be a little clearer, perhaps, if we return to Fig. 724, and by the aid of that drawing are able to realize that the isobars on the map represent the intersection of surfaces of equal pressure with the level of the sea. When this is clear, it becomes almost self-evident that the air must slide down the inclined isobaric surfaces, whose edges are represented in Fig. 724, and that the warping of those isobaric surfaces, as revealed by the sea-level map and interpreted by Fig. 724, has been such as to produce winds blowing from the tropics toward the equator on the one hand and toward the poles on the other. In fact, this is the important explanation for those "trades" that blow steadily throughout the year in the directions just named, winds that were early known to navigators of the oceans and to some of the inhabitants of the lands. While the deformation of the isobaric surfaces thus serves to explain the origin and direction of these winds, we have not as yet, however, any explanation for the irregular distributions of pressure and of that warping which causes the winds.

On comparing the positions of the belts of high and low pressure in January and July with the belts of temperature for the same months, as shown in Figs. 715 and 716, we notice some striking coincidences. It is found that the axis of the equatorial belt of low pressure lies somewhat south of the equator in January, just as the axis of the equatorial belt of high temperature lies very close to the equator in the same month; while in July the two belts, so far as they are recognizable, have both moved to more northerly positions. This suggests a possible connection of some sort between the general distribution of temperature and the general distribution of pressure. Again, comparing the position of the centers of high pressure in January with the position of centers of high and low temperature in the same month, it is found that the center of low temperature characteristic of northern Asia corresponds almost exactly to a center of high pressure. The center of high pressure over North America in January corresponds to an area of marked low temperature, while the centers of marked high temperature over Africa, South America and Australia are represented by centers of relatively low pressure. In other words, the low pressures in January prevail over land areas that are being strongly heated in the southern hemisphere, while the centers of high pressure in the same hemisphere prevail over the relatively cooler ocean bodies. On the other hand, in the northern hemisphere in January centers of high pressure are found over the relatively much colder continental areas of North America and northeastern Asia, while the strong low-pressure area is located over the north Atlantic and north Pacific.

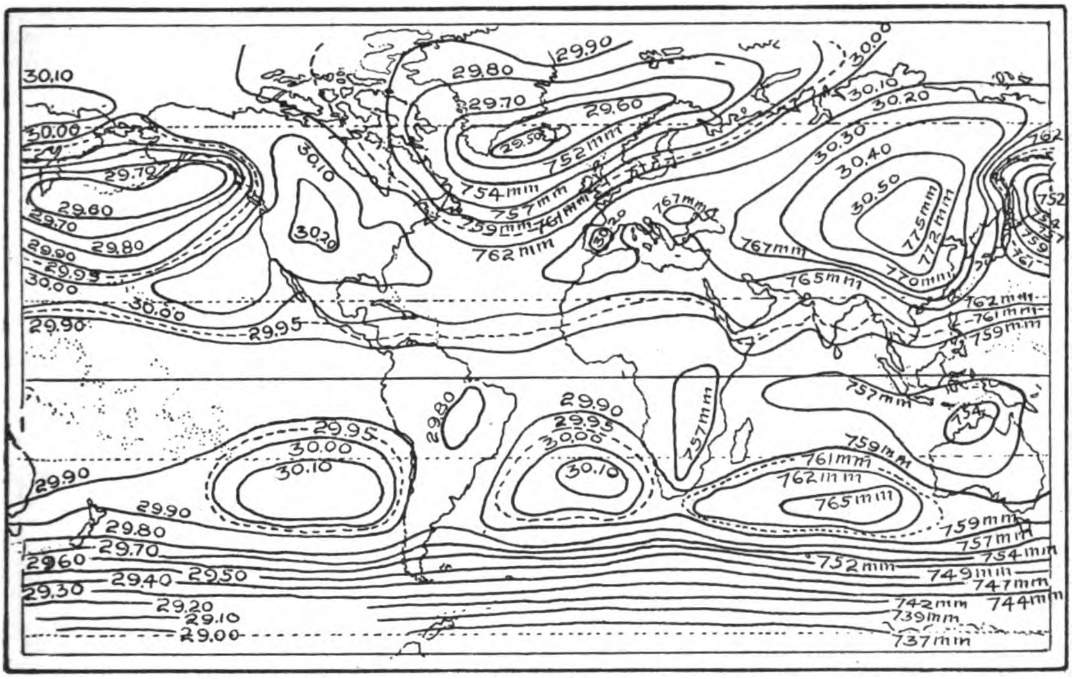


Fig. 725. World isobars for January. (After Bartholomew.)

Passing to the maps of temperature and of pressure for July, Figs. 716 and 726, we find centers of low pressure prevailing over Asia and North America, regions which we know are the centers of high temperature, while centers of high pressure are well marked over the central north Atlantic and north Pacific in the northern hemisphere. The southern hemisphere, which is predominantly a water hemisphere, shows zones of high pressure reaching from the eastern part of the southern Pacific across South America, the south Atlantic and south Africa to the southern Indian ocean. So far the relation between temperature and pressure, if there be any, seems to indicate that low temperatures imply high pressures, and vice versa.

Relation between temperature and pressure.

The preceding study of the maps for the globe showing temperature and pressure suggest the possibility of some causal relation between these two conditions of the atmosphere. Closer study of the changes in condition of the atmosphere produced by changes in temperature over relatively limited areas, shows that the apparent relation between high temperatures and low pressures at the surface is an actual one. Fig. 727 presents one of the earliest stages in the changes in pressure resulting from changes in temperature of the atmosphere near the surface of the earth. The dotted horizontal lines, aa, bb, etc., of the figure show the position of a number of isobaric surfaces under uniform conditions of surface temperatures. As the temperature rises about the central point, W, the lower layers of air expand, lifting the layers lying above them, thus bending the isobaric surfaces into the positions shown by the continuous lines, aa, bb, etc. The successive isobaric surfaces thus displaced by the increased temperature of the atmosphere have suffered increasing displacement upward, since each layer is raised above its original position, not only as the result of its own expansion but as the result of the total expansion of all the layers beneath it; consequently, the uppermost isobaric surfaces will suffer the greatest amount of bending and displacement. The air lying over the regions of greatest displacement of the isobaric surfaces must now begin to move outward in the direction of the arrows, since the pressure along the dotted lines is greater in the immediate vicinity of the column of air over W than it is at the sides of the region represented in the figure. The greatest amount of air moves away toward the sides in the upper layers, and it moves more rapidly since there the difference in pressure is most marked. Another way of explaining this movement of the air is to consider the warped surfaces as so many inclined planes down which the individual masses of air tend to move, just as a car tends to roll down hill when set free from its fastenings. The steeper the hill the faster the car will move, and the more strongly warped the individual isobaric surfaces are the faster does the air move down them to lower levels.

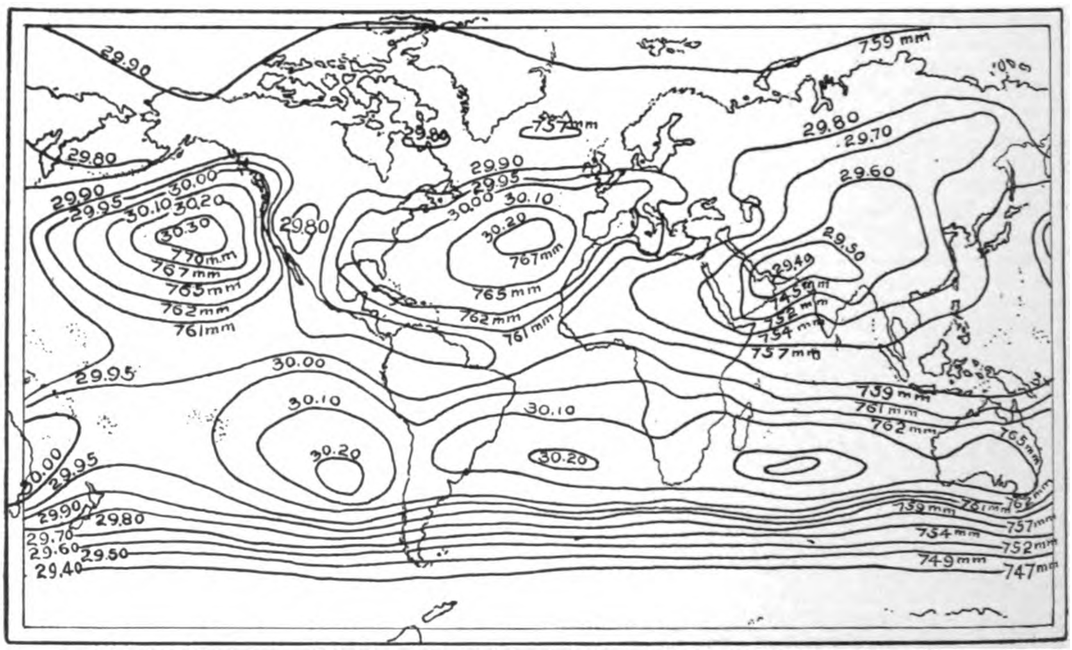


Fig. 726. World isobars for July. (After Bartholomew.)

The result of this upward movement of the air over W is to relieve the pressure on the earth's surface at W, while the heaping up of the air around the margin of the disturbed section tends to increase the pressure at the earth's surface, so that shortly after the isobaric surfaces have become warped by the increasing temperature we find the

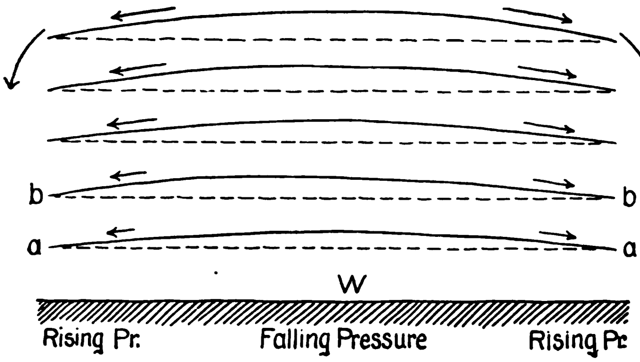


Fig. 727. Beginning of circulation over heated center. The lines aa, bb, etc., show position of a number of isobaric surfaces under uniform conditions of surface temperatures. The rising temperature over W bends the surfaces as shown.

pressure falling at W and rising on either side of it some distance away. If, now, the temperature at W continues to rise, or even if it simply remains distinctly warmer than the surrounding regions, the outflow of air from the upper strata begins to require an inflow to take its place along the lower strata. Thus arise the conditions of pressure presented in Fig. 728, where we find the isobaric surfaces warped upward in the upper levels and warped downward in the lower levels, due to the decreased pressure near the earth's surface over W. On the other hand, around the margins of the warm center, W, is found an upward displacement of the isobars near the surface, due to the piling up of the air in those regions as it flows out from the upper layers over the warm center. Thus there is set up over a warm center the circulation indicated by the arrows in Fig. 728, and we see that this circulation is due to the displacement of the iosbaric surfaces from their undisturbed original horizontal positions.

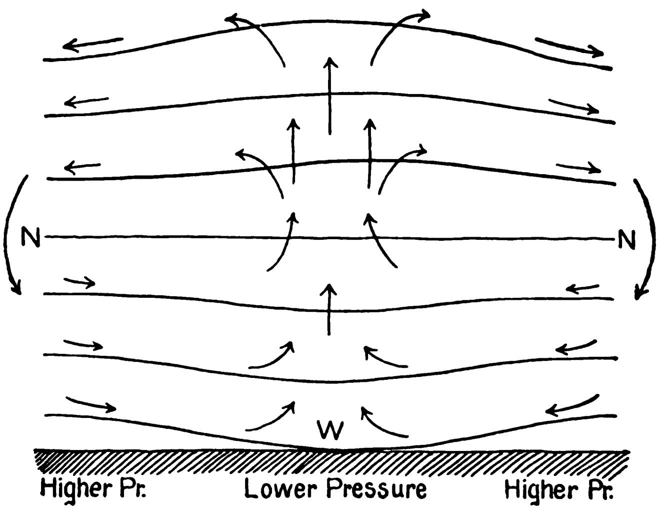


Fig. 728. Circulation over heated center. The isobaric surfaces are warped upward in the upper levels and downward in the lower levels, due to the decreased pressure near the surface over W.

The arrangement of the isobaric surfaces and the resulting movements of the atmosphere over a cold center surrounded by relatively warmer regions are shown in Fig. 729, which hardly needs detailed explanation, since the processes here involved are but the direct opposite of those just outlined. The illustration shows that a region characterized by relatively low temperatures tends to become a center of higher pressure than that which characterizes the surrounding warmer regions, so that the air near the surface of the earth is moving away from such a center of low temperature and high pressure, while in the upper atmospheric layers the air is moving inward and downward toward such a center.

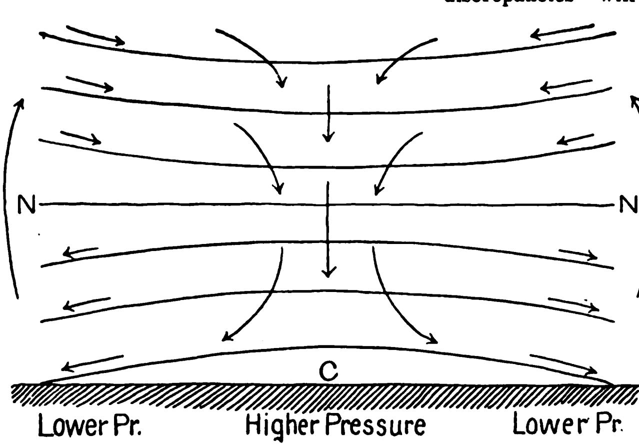


Fig. 729. Circulation over cold center. A region of low temperatures tends to become a center of higher pressure than that which characterizes the surrounding warmer regions, so that the air near the surface is moving away from, and that in the upper layers is moving inward and downward toward such a center.

Returning to the maps of the world showing distribution of pressure and of temperature (Figs. 723 and 714), we are now better able to understand the distribution of pressure along a meridian as shown in Fig. 724. Here we find the isobars dipping down toward the warm region over the heat equator and trying to rise over the cooler regions lying outside the tropics. The isobaric surfaces, however, do not agree precisely with the conditions just outlined in that they descend toward the surface of the earth, i.e., the pressure decreases in the vicinity of the two poles, the regions of greatest cold, while, according to the above explanation, one would expect to find here the highest pressures. These discrepancies will be explained when we consider the winds of the globe in more detail. The chief point to notice here is that, with a single exception, the derangement of the isobaric surfaces, as reflected in the courses of the isobars on the maps, coincides with the

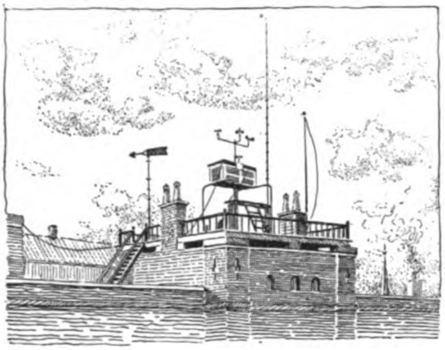


Fig. 730. Method of exposing instruments in cities.

derangement of those surfaces which we would expect to find if it resulted from an unequal distribution of temperature. This is made much more striking when we contrast the maps of temperature and pressure for January (Figs. 715 and 725) with those for July (Figs. 716 and 726), since these maps show distinctly a change in the distribution of the pressure as the temperatures over lands and waters change. This change in pressure is distinctly reflected in the change of direction of some of the winds, particularly those which blow from Asia to the Indian ocean, or vice versa.

We have found that the zones of highest and lowest temperatures which surround the globe move northward in July and southward in January; therefore, we shall not be surprised to find that the winds dependent on these belts of temperature and pressure also shift their positions from season to season. Further, the deformation which an unequal distribution of temperature produces in the isobaric surfaces need not be limited to the greater areas illustrated in the maps of the world. More restricted areas of the earth's surface, as we have already seen in the discussion of temperature, may present stronger contrasts in temperature, and we may therefore expect to find corresponding contrasts in pressure that will logically produce characteristic winds.

Section IV—Winds

In studying the movements of the earth's atmosphere, it is necessary to determine with as much accuracy as possible three features: the direction from which the wind blows, its velocity, and the force with which it blows against resisting objects in its path. The last characteristic is a function of the size and shape of the obstacle, so that for ordinary purposes of study it is sufficient to determine only the first two. For this purpose there have been invented several types of instruments, the best known of which, the wind-vane and the whirling anemometer, are today familiar objects to those living in the vicinity of meteorological observing stations. The weather-vane, as shown in Fig. 730, consists of a light rod carrying an arrowhead at one end and attached firmly to a pair of slightly spreading boards at the other end. This fishtail-like attachment has the advantage of keeping the wind-vane pointing more steadily in the direction from which the wind comes, so that sudden eddies or gusts shall not deflect the vane too much from the average direction of the wind and thus make it difficult to read the same readily. An important attachment to the wind-vane is an accurately oriented diagram of the eight compass points, either attached to the ceiling of the room immediately under the vane or connected with the wind-vane rod by some mechanism that enables it to lie conveniently on a table. Every station should have a wind-vane, for it is most important that we have records of the wind directions near the surface of the earth as well as of the direction of the lowermost cloud layers. The two directions often seem to be the same, but careful observers have noticed that in reality there is a more or less constant divergence between them, the lower clouds moving in a direction slightly to the right of surface winds. As will be pointed out, this divergence must be because the deflective force of the earth's rotation is more free to act on air at the level of the lower clouds than it is on the air immediately in contact with the irregular surface of the earth.

The instrument known as the anemometer, used for registering the velocity of the wind, consists of two light movable short metal arms attached rigidly at right angles to the top of a carefully adjusted rod. At the extremities of the cross-arms are attached hemispherical cups with the concave sides turned in the same direction. This instrument, as shown in Fig. 731, is provided at the lower end of the supporting spindle with a worm and a series of accurately-made cog-wheel dials which record the number of miles traveled by the wind. The form shown in the illustration is known as the Robinson anemometer and is adopted by most meteorological stations. Other forms, some of them working on slightly different principles, have also been invented. The chief disadvantage of all forms now in use arises from the inertia of the arms and cups, causing the instrument to register much higher velocities during severe blows than probably are actually attained by the wind. Investigations of this instrument made by the United States Weather Bureau have shown that the error thus introduced into the records during very high gusts

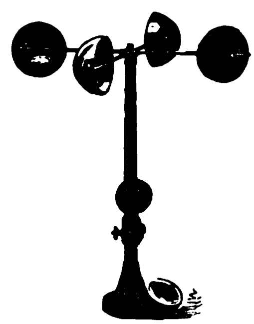


Fig. 731. Robinson's anemometer, the standard instrument for measuring the speed of the wind.

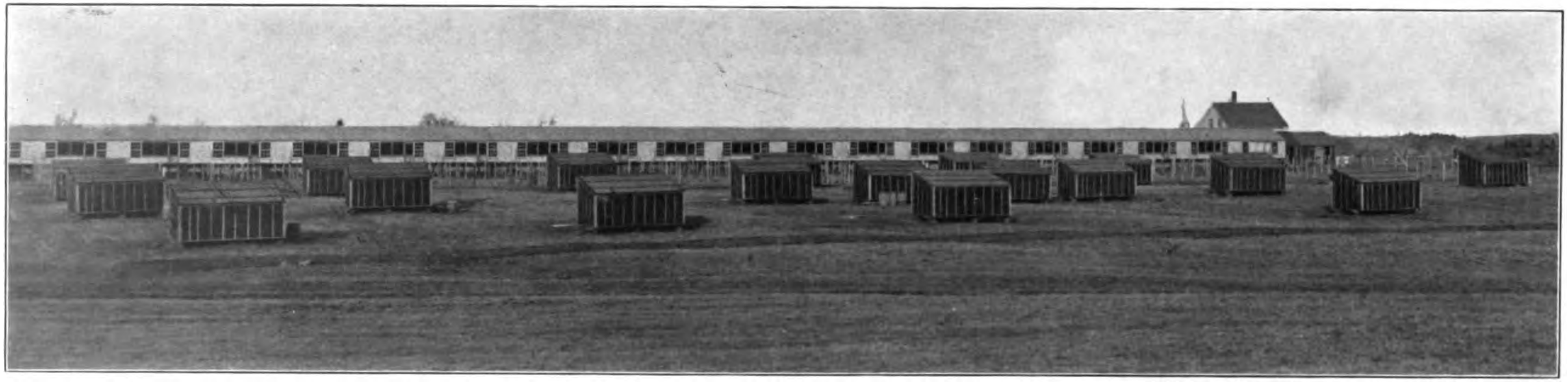


Plate XXV. Poultry establishments in the East. The upper picture is a house 400 feet long, with each pen-front open, and colony houses backed to the sun (Go-Well Poultry Farm, Orono, Maine). The lower picture shows a house 128 feet long, grain-house just in rear (Lakewood Farm, Burrsville, New Jersey) may amount to as much as 20 per cent. This instrument, although valuable for determining the velocity of the wind, gives but an imperfect idea of the pressure it exerts on objects in its path; so far, no satisfactory instrument has been invented to record this pressure. Perhaps one of the chief reasons for this is that the resistance offered to the movement of a mass of air depends not so much on the area of the obstacle as on its shape and form.

The general circulation of the atmosphere.

It has been pointed out (page 567) how temperature influences the arrangement of the isobaric surfaces in the earth's atmosphere, and how disturbances of these surfaces may result in those movements of the atmosphere which we call winds. We now turn to the study of these winds, and first take up those that are characteristic of the earth as a whole.

We have seen that the source of all the energy on the earth's surface is the sun. Under the simplest terrestrial conditions we would expect to find a region of high temperature just over the equator grading off on either side to regions of minimum temperatures at the poles. Such a simple distribution of temperature would produce a very simple distribution of pressure over the earth's surface, namely, a belt of constant low pressure at the equator and high pressure over the two poles. On a planet characterized by such a simple distribution of pressure, the winds would all tend to blow from either pole toward the equator and, if the earth did not rotate on its axis, these winds would blow along paths corresponding to the meridians of the ordinary maps. In the upper layers of the atmosphere, on the other hand, there would be a set of return currents carrying the heat away from the equator back along the meridians to the poles, slowly descending as it progressed.

The actual conditions of the earth, however, differ from these simple conditions in two respects. First, the earth is rotating rapidly on its axis and, second, the earth's surface is unequally divided into rough lands and smooth oceans. The consequence of rotation is that the winds are unable to follow the meridians on their way from the cold polar regions toward the warm equatorial regions. They are deflected to the right of such a course in the northern hemisphere and to the left in the southern hemisphere, so that instead of meeting each other head on at the equator they meet obliquely. Under these conditions, then, the winds would be prevailingly northeast winds in the northern hemisphere, and in the southern hemisphere prevailingly southeast winds. This tendency to be deflected to one side or the other of a direct course is shown by all bodies free to move on the earth, and has been best illustrated in the experiments made by Foucault, with the long pendulum. The force which the diurnal rotation exerts on such free-moving bodies is known as the deflective force of the rotating earth, and tends to produce a characteristic right-hand deflection of all free-moving bodies in the northern hemisphere and a left-hand deflection of free-moving bodies in the southern hemisphere. This deflection is strikingly exhibited in the case of the surface winds blowing out from a region of high pressure, or in toward a region of low pressure. In such a simple circulation as is referred to above, the cooler overhead currents flowing toward the poles from the equator would also feel this deflective force, and the overhead currents about the poles would thus be set into a whirl, which would tend to heap the air somewhat over a zone around the poles, at the same time withdrawing some of the air from the region immediately over the poles. Thus there would be produced secondary regions of lower pressure over the poles and of higher pressure between the poles and the equator. Perhaps the distribution of pressure actually observed over the earth's surface, presented diagrammatically in Fig. 724, is to be explained in this way.

The next step leads to the winds resulting from this modified distribution of pressure, that is, to the general wind conditions as they actually appear on the present rapidly rotating sphere. The secondary zones of high pressure lying nearly over the tropics would result in a set of winds blowing from temperate latitudes toward the poles on the one hand, and from temperate latitudes toward the equator on the other hand. If it were possible for such a distribution of surface pressure to obtain on a globe that is not in rotation, the winds resulting from it would of course tend to move down the steepest slopes of the isobaric surfaces, which would be at right angles to the equator. Since the earth is in constant rotation, the deflective force of this rotation continues to be exerted on this set of winds, with the result that we have the winds as presented diagrammatically in Fig. 734. This shows a zone of winds blowing from temperate latitudes toward the equator but deflected to the right in the northern hemisphere, and thus arise the northeast trade-winds. A corresponding set of winds in the southern hemisphere, blowing from the south temperate latitudes toward the equator, have experienced a corresponding left-hand deflection, and constitute the well-known southeast trade-winds. From the temperate zones of high pressure there are also sets of winds blowing more or less poleward, which are correspondingly deflected to the right in the northern hemisphere, giving a broad zone of west-northwest winds, and of west-southwest winds over corresponding latitudes in the southern hemisphere. Such winds as those presented in these figures may be appropriately called planetary winds; they are also spoken of as "the general circulation of the earth's atmosphere."

Such winds would be permanent in their character, position and velocity if the heat equator always coincided with the geographical equator. In discussing the distribution of temperature, it was pointed out that the inclination of the earth's axis, combined with the yearly revolution around the sun, causes the heat equator to migrate along the meridians from season to season. Such migrations of the heat equator, give additional characteristics to these winds primarily planetary in character. The maps (Figs. 732, 733, 735 and 736) show distinctly that at one season the heat equator, by reason of its extreme northerly position, must cause the southeast trades to cross the geographical equator in some districts, while at the opposite season the southern position of the heat equator may cause certain winds of the northern hemisphere to extend into the southern hemisphere. Whenever one set of trade-winds is drawn across the terrestrial equator into the opposite hemisphere, the deflective force prevailing in that hemisphere will be exerted on them as on all other winds there. For example, the southeast trades of the southern Indian ocean are regularly drawn across the equator in July, as is shown in Fig. 736, and there falling under the influence of the right-hand deflection of the northern hemisphere are converted into what are truly southwest trades for part of the year. To a less extent, a corresponding change in direction is suffered by the January winds over the Indian ocean, their northeasterly character over the northern Indian ocean being changed to a northwesterly one in the vicinity of the Seychelles and Chagos islands.

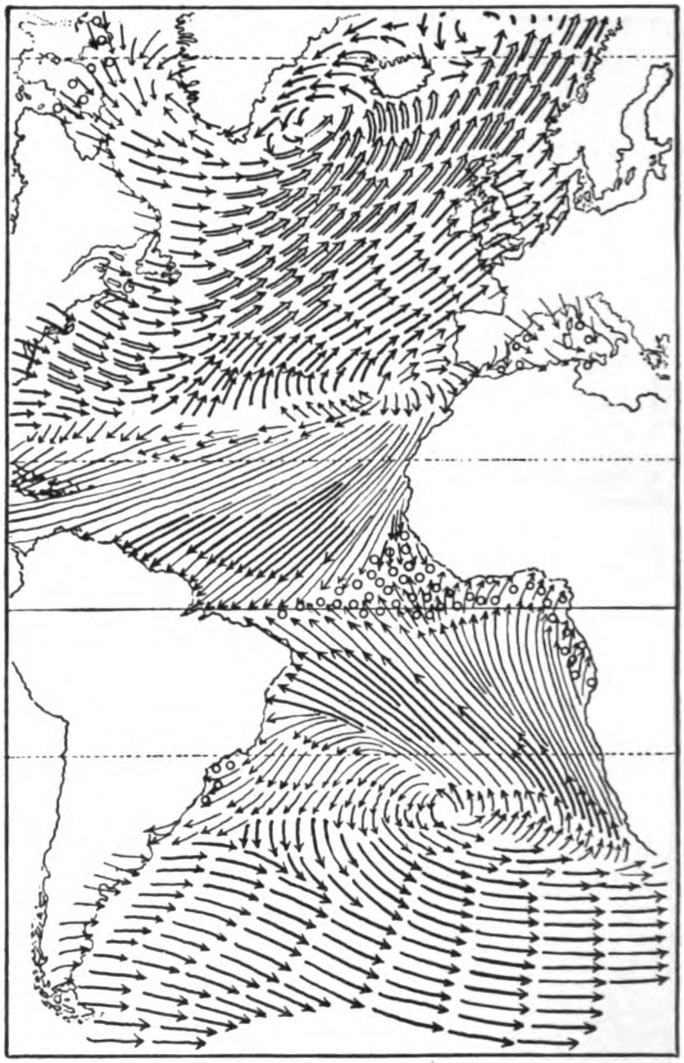


Fig. 732. General winds of the Atlantic for January. Long arrows indicate steady winds; shorter arrows, variable winds; heavy arrows denote gales or strong winds; light arrows, moderate winds; small circles indicate calms. (After Davis, Elementary Meteorology.)

The northeast and southeast trades are separated from each other by a comparatively well-defined belt characterized by weak and shifting and generally ascending currents of air in the immediate vicinity of the equator. This belt is known as the doldrums. The boundaries of the two trade-winds and of the doldrums for opposite seasons of the year is given in the table below:

THE BOUNDARIES OF THE DOLDRUMS AND THE TRADES.

	Atlantic ocean		Pacific ocean	
	March	September	March	September
N. E. Trades	26° N.– 3° N.	35° N.–11° N.	25° N.– 5° N.	30° N.–10° N.
Doldrums	3° N.– 0° N.	11° N.– 3° N.	5° N.– 5° N.	10° N.– 7° N.
S. E. Trades	0° N.–25° S.	3° N.–25° S.	3° N.–28° N.	7° N.–20° S.

This table shows that even on this planet, whose surface is diversified by land and water, mountain chains and plains, there is a narrow belt close to or on the equator that is under the dominion of the northeast trades at one season, under the southeast trades at another season. This belt is called the sub-equatorial belt. Corresponding movements in the zones dominated by the westsouthwest and westnorthwest winds must also take place, so that there are also two belts more or less parallel with the sub-equatorial belt and separated from it by the trade-winds. These two belts are called the northern and southern subtropical belts respectively. Such a set of winds as those just described, subject to bodily shifting from season to season, is distinctly characteristic of the earth. The fact and

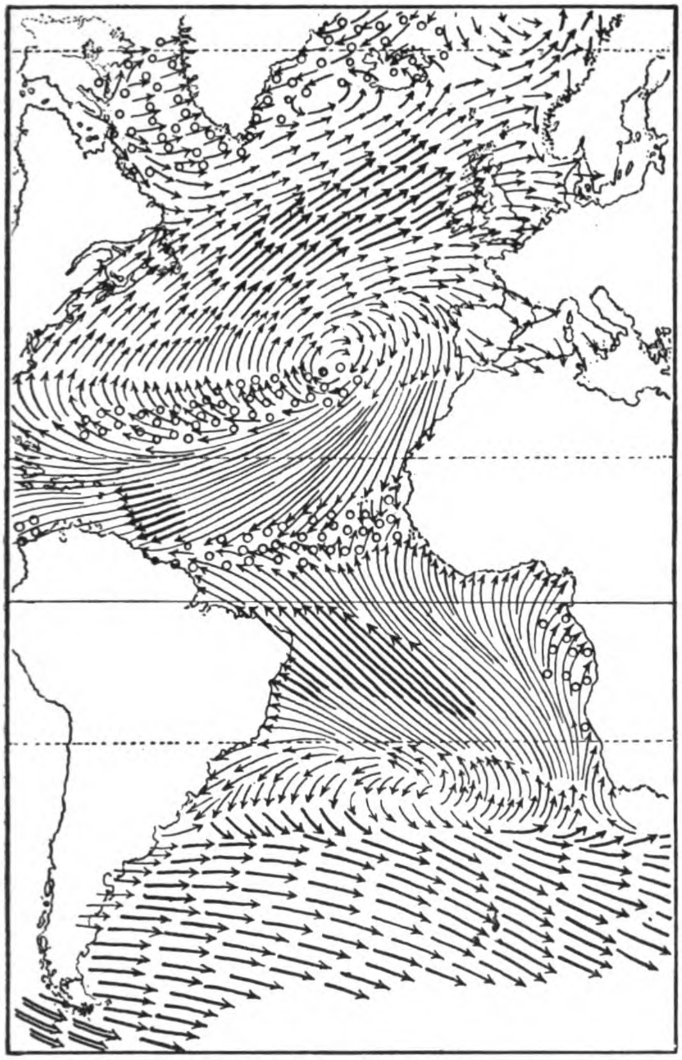


Fig. 733. General winds of the Atlantic for July. Long arrows indicate steady winds; shorter arrows, variable winds; heavy arrows denote gales or strong winds; light arrows, moderate winds; small circles indicate calms. (After Davis.)

the amount of shifting are due primarily to the inclination of the earth's axis; therefore, these winds may be classed as terrestrial winds in distinction from the planetary winds previously described.

These terrestrial winds are subject to interruptions imposed on them by the unequal distribution of land and water and by the obstructing inequalities of the surfaces of the continents. The unequal distribution of land and water produces, even at the same time of year, marked contrasts in temperature, and therefore in pressure, between contiguous regions of the lower layers of the atmosphere. Each body of water in nearly every case produces opposite conditions of temperature and pressure from those prevailing over neighboring land masses, and these conditions are subordinate only to the great distribution of pressure characteristic of the earth as a whole. These subordinate interruptions to the terrestrial distribution of pressure undergo seasonal alternations, since the high pressure on the lands characteristic of the winter season will gradually change to a low pressure as summer approaches. In several cases these contrasts between land conditions and water conditions are sufficiently strong almost to counteract the terrestrial influences. This is notably so in the case of the continent of Asia as contrasted with the Indian ocean, and to some extent also the case with Australia in contrast with its surrounding oceans. During the northern winter the cold air over Asia flows outward, then southward and southwestward toward the northern and equatorial Indian ocean. With the reversal of temperature conditions in summer, the air is drawn in spirally toward Asia from the bordering oceans, flowing northeastward from the Indian ocean across the southern coast of Asia. At this season, the northern Indian ocean, which normally lies in the belt of the northeast trades, is swept by a completely reversed current of air; but in the winter months it is characterized by northeast winds, which, however, could not be called trade-winds, since they come from the high pressure over Asia. Such winds subject to seasonal reversals, due to contrasts between continents and oceans, are called continental monsoons. They form perhaps the most important class under continental interruptions to the terrestrial surface winds. The continental expansion of the island of Australia enables it to exert something of this same power of reversal on terrestrial winds, while similar seasonal winds characterize the Texas coast, the Gulf of Mexico and the Iberian peninsula. Less distinct evidences of this monsoon influence are found over the Atlantic ocean near northern Africa. Such winds as the monsoons may also be termed seasonal winds, since they change with the changing seasons.

The interruptions to the terrestrial winds produced by continental obstructions, result chiefly from the interposition of high mountain ranges or plateaus to those winds. Such obstructions to terrestrial winds are best expressed by the resulting increase in rainfall, to windward of the high mountain ranges that characterize the west coasts of North and South America and lie directly opposed to the free passage of the trades. The general decrease in the velocity of the winds over the land as compared with the winds over the oceans is another evidence of the obstructions presented by land surfaces to the movements of the terrestrial winds.

Another class of winds of much less importance than these from a broad point of view, also constituting interruptions to the terrestrial winds, is those that may be called the diurnal winds. The chief characteristic of these winds is a reversal of direction that occurs with more or less regularity every twenty-four hours. The best known examples of these diurnal winds are the land and sea breezes and the mountain and valley winds. In the case of the land- and sea-breeze, the wind owes its existence to the difference in pressure existing between land and water, and its regularly alternating character to the diurnal changes in temperature gradient over the same. During the day, the rapidly warming air in contact with the land produces a zone or center of lower pressure, while the less rapidly warming water of the lake or sea makes possible the existence of a relatively higher pressure over it. The result is that during the day there is an appreciable, sometimes a very marked, movement of the air from the water to the land. During the night, however, the temperature conditions rapidly become reversed, owing to the much greater rapidity with which the land and the air in contact with it can cool. The wind blowing from the water to the land during the day is known as the sea-breeze or lake-breeze. This wind generally springs up late in the forenoon and blows until late in the afternoon, then follows a calm until late in the evening. The reversal from the day conditions takes place about midnight and the land-breeze blows steadily until early morning.

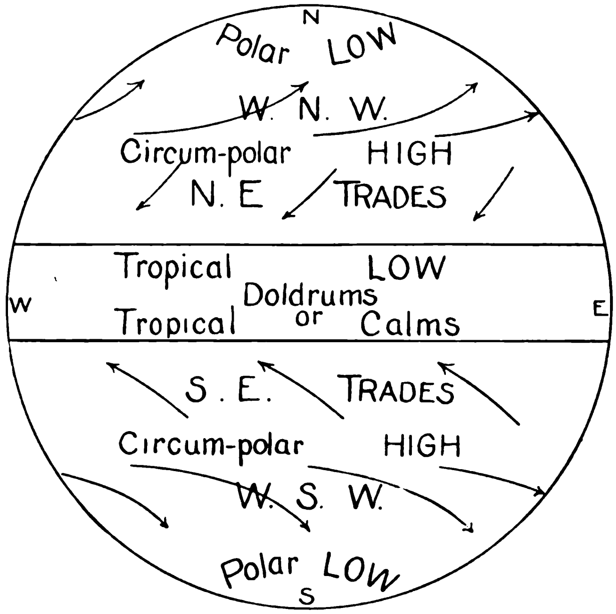


Fig. 734. Diagrammatic representation of the constant earth winds.

The currents thus daily set up along the coasts are very shallow in depth and, in most cases, do not

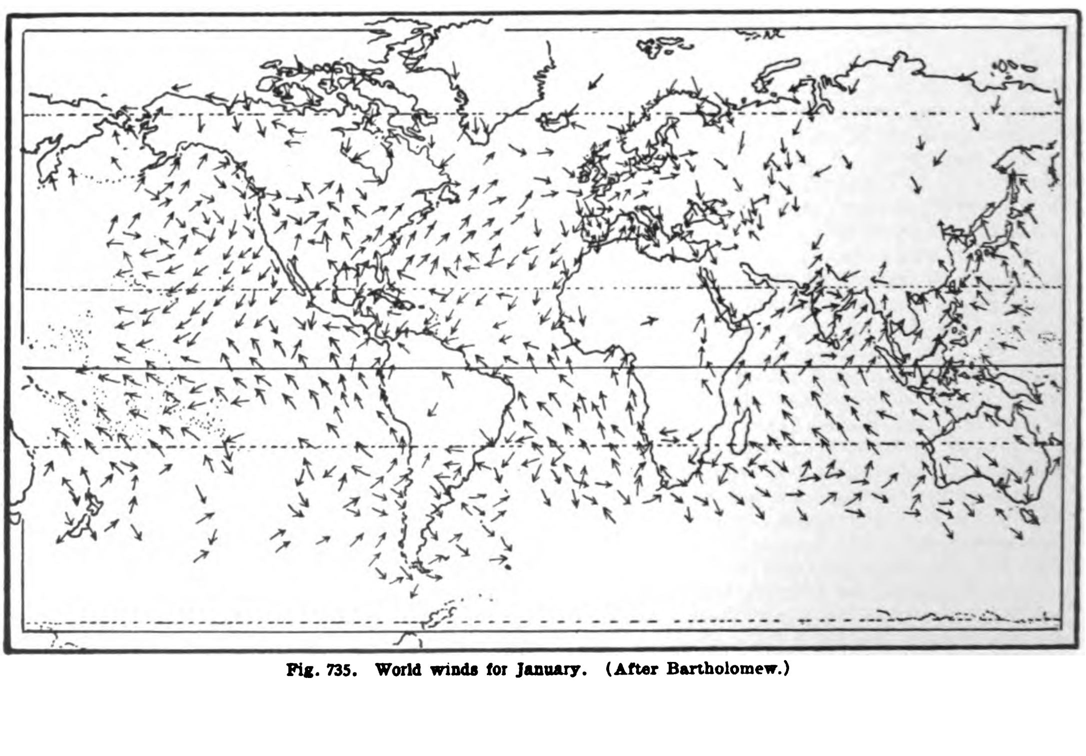


Fig. 735. World winds for January. (After Bartholomew.)

play an important part in the movements of the atmosphere. Certain localities, however, are so situated that one of these diurnal currents reinforces a terrestrial current, in which case the usually insignificant diurnal wind becomes very prominent. This is illustrated in the case of the sea-breeze on the western coast of South America. Here, the sea-breeze that arises daily blows from the west toward the land and reinforces the prevailing west wind, so that in summer a cool wind blows during the day; while during the night the land-breeze reduces the prevailing west wind to a calm or may even reverse it. Similar variations in the strength of the terrestrial winds have been observed on the eastern coast of the same continent in the trade-wind belts.

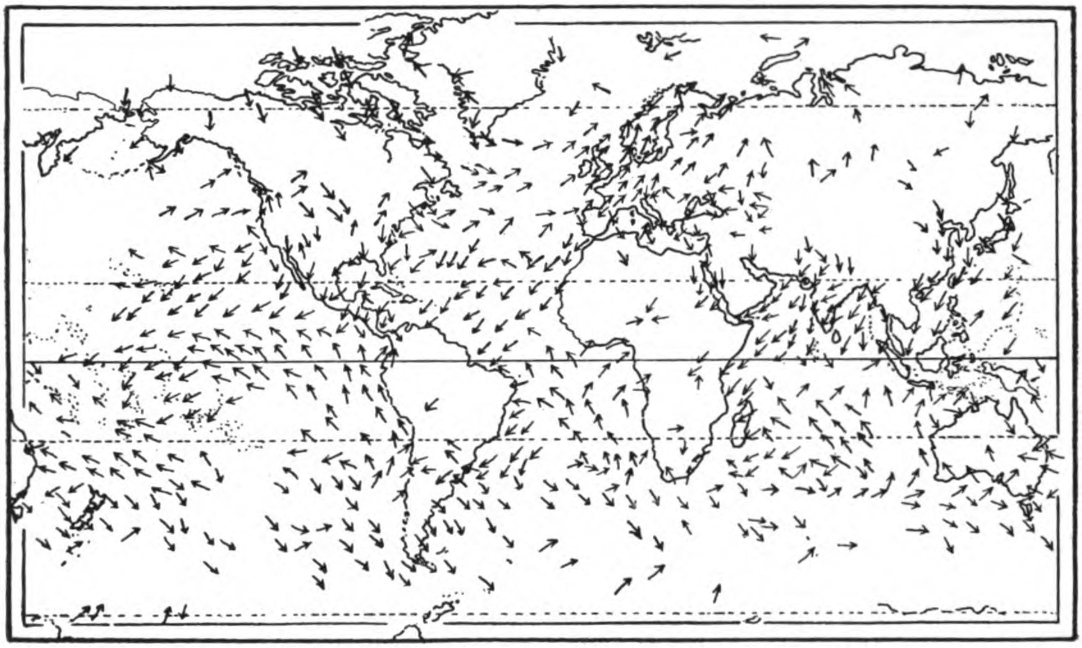


Fig. 736. World winds for July. (After Bartholomew.)

In mountainous regions, the days and nights experience reversals in the winds similar to those of the coastal regions described above. The explanation of the day winds in this case is somewhat different from that of the sea-breeze along the coast. The conditions of distribution of pressure in mountain and valley are illustrated in Fig. 737, where the dotted lines a_1, a_2, a_3, etc., represent the positions of the isobaric surfaces under quiet conditions of the atmosphere. As the lower levels of the air in the valley become warmed by the sun, these level isobaric surfaces become raised to the positions shown by the lines, b, b, etc. Here, as in Fig. 727, the upper surfaces suffer the greatest amount of deformation over the center of the valley, but none of the isobaric surfaces are lifted at the points where they touch the mountain summits, since there is no air under them whose expansion would serve to deform them; consequently, these surfaces all present slopes from the center of the valley toward its sides. This peculiarity causes the air along the sides of the valley to slide toward the mountain slopes and there take on an upward movement as the resultant between the laterally moving currents and the upward sloping surface of the ground. Thus, during the day there arises an upward moving current along the slopes and the axis of the valley. During the night, on the other hand, the air cools most rapidly where it lies in contact with the rapidly radiating rocks, and consequently soon begins to contract and slide down the slopes into the valley and down the valley toward its mouth. This gives rise to what are called valley winds in the night and to mountain breezes in the day.

Another class of winds is noted, which includes a number of irregular kinds, but these will be considered under cyclonic storms.

SECTION V. STORMS

In the preceding pages we have considered the general movements of the earth's atmosphere and several classes of winds, the directions of which are characteristic of certain localities or seasons. There remain a number of different kinds of winds, the directions and even the existence of which are not constant, but which appear and disappear more or less irregularly. These winds are all associated with what are popularly called storms; and it has been found possible to classify storms according to the areal extent and the degree of violence of the winds accompanying them. Disturbances of the atmosphere having a diameter of between 500 and 1,000 miles, developing winds of only moderate velocity and associated with somewhat circumscribed areas of low pressure, are particularly characteristic of those belts on the earth's surface dominated by the prevailing westerly winds, i. e., of temperate latitudes. Such storms are now called cyclones[1] by nearly all well-informed people. They are not dangerous to life except as they may involve shipping along the coast of lakes and oceans. The second class, similar in many ways to the foregoing but distinguished from it by the fact that they have a much smaller diameter and are always accompanied by very violent winds strong enough at least to unroof many of the houses in their paths, if they do not entirely demolish them, includes the storms known as whirlwinds, or tornadoes, and hurricanes. The third class properly includes those of the type known as thunder-storms. These storms are characterized by having one dimension much longer than the other and by motion nearly at right angles to the longer side.

Cyclones.

The first class of storms, called cyclones, has been divided into two sub-classes, tropical and extra-tropical, depending on the regions in which the storms originate. Of these two sub-classes, the tropical cyclone or hurricane is so much more violent and so dangerous to shipping, by reason of its preference for oceans, that it early became an object of careful study on the part of mariners. As it presents in a somewhat accentuated way all of the characteristic features of the class of cyclonic storms, it is worth while to consider one of these tropical cyclones in some detail.

[1] Attention is drawn to the distinction between the term *cyclone* as here used to designate a storm area of broad extent accompanied by high but not destructive winds, and the one-time popular use of this term to designate those storms of very small diameter and violent character which are now more commonly called *tornadoes*. The term cyclone was originally applied to a class of storms intermediate between the two just mentioned and particularly characteristic of the tropics, which is now known by the names of *hurricane, typhoon* and *baguio*.

Tropical cyclones, hurricanes.—The approach of a tropical cyclone is first announced by the barometer showing a slight increase over the usual uniform pressure characteristic of the tropics. This preliminary rise is soon succeeded by a decided fall in pressure that rapidly increases. At the same time, feather-like, high-floating clouds begin to spread over the sky from the point above the center of the storm, which soon becomes evident by its heavy mass of cloud. The velocity of the wind at first is almost nothing, and the air becomes rapidly loaded with moisture, which gives a sultry character to the atmosphere. As the storm approaches, the temperature remains constant, but the wind rapidly increases in force as the barometer falls and the high feathery clouds give place to the heavy masses of cloud which cut off the sunlight, and soon increase in thickness to such an extent that the sky appears a uniform lead color. As the winds freshen they are noticed to blow in a direction somewhat to the right (in the northern hemisphere) of the low mass of dark clouds that mark the distant storm-center. Clouds can now be noticed forming and flowing in to join the central dark mass; the winds increase to a gale; the waves almost keep pace with them; rain soon begins to fall, at first in slight quantities. The center of the storm progresses at a rate of eight to twelve miles an hour, and heralds its nearer approach by the now very rapid fall in the barometer, the roaring of the wind which becomes of terrific strength, the flashes of lightning and the torrential downpour of the rain. Occasionally a ship has penetrated to the center of one of these cyclones and escaped with living observers to tell what happens there, and one or two cases where the storm-center has passed over the land have given an opportunity, by means of self-recording instruments and personal observations, to learn that the immediate center of the storm, perhaps ten to twenty miles in diameter, is characterized by an almost cloudless sky and perfect calm. As the storm winds on the farther side of this calm center space, commonly known as the eye of the storm, approach, they present all the features of violence

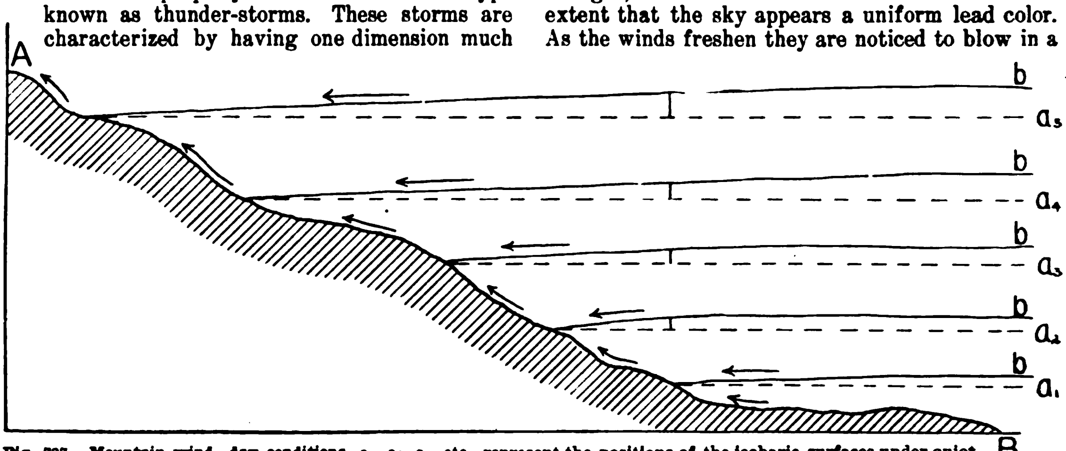


Fig. 737. Mountain wind—day conditions, a_1, a_2, a_3, etc., represent the positions of the isobaric surfaces under quiet conditions of the atmosphere; b, b, etc., the positions of the isobaric surfaces when the valley becomes warmed. The upper surfaces suffer the greatest amount of deformation over the center of the valley.

that characterize the winds blowing in the front of the storm, but the direction of the winds is now the reverse of those that preceded the storm's eye. After the passage of the storm-center, the pressure rises again as rapidly as it fell, the rain decreases steadily and rapidly, and the winds show corresponding decrease in velocity; their direction changes steadily, the velocity decreases, and they gradually die away as the storm moves off. The lower clouds draw away, quickly followed by the high-flying, feathery cirrus, and, in less time than was required for the storm to approach, all marks of the storm have disappeared. The approach of such a storm is often heralded several days in advance by the increasing violence of the surf along the coasts, due to the fact that the great storm waves whipped up by violent winds attain a velocity greater than that of the storm-center, and are thus outrunning it. Fig. 738 presents in a graphic way the simultaneous changes in wind velocity, temperature, atmospheric pressure, wind direction, rain and atmospheric moisture which accompany such a storm. They were recorded at Manila, Philippine islands, during the passage of a hurricane (typhoon), in October, 1882, and show very clearly the changes just described.

The distribution of the pressure around such a storm has been found to be very uniform. It is represented on the maps by almost circular concentric isobars, whose values indicate unusually low pressures and whose crowding near the eye of the storm indicates very clearly the very strong barometric gradient characteristic of such storms. The high winds that accompany these hurricanes have an almost circular direction about the center, and the less accurate observations of the early mariners describe them as being such. A large number of careful observations collected in later years show that they have a very wide deflection from the short direct path to the center of the storm, and that this deflection increases as the center is approached, until, in the immediate vicinity of the latter, they do indeed appear to have an almost perfectly circular course. These observations on the course of the lower winds, together with the observations of high-flying clouds proceeding away from that part of the sky immediately over the center, lead irresistibly to the conclusion that these same centers consist of cyclonic eddies or whirlpools in the lower atmospheric strata. In these storms, the air has undoubtedly an ascending spiral movement flowing in violently at the base and pouring out in all directions overhead.

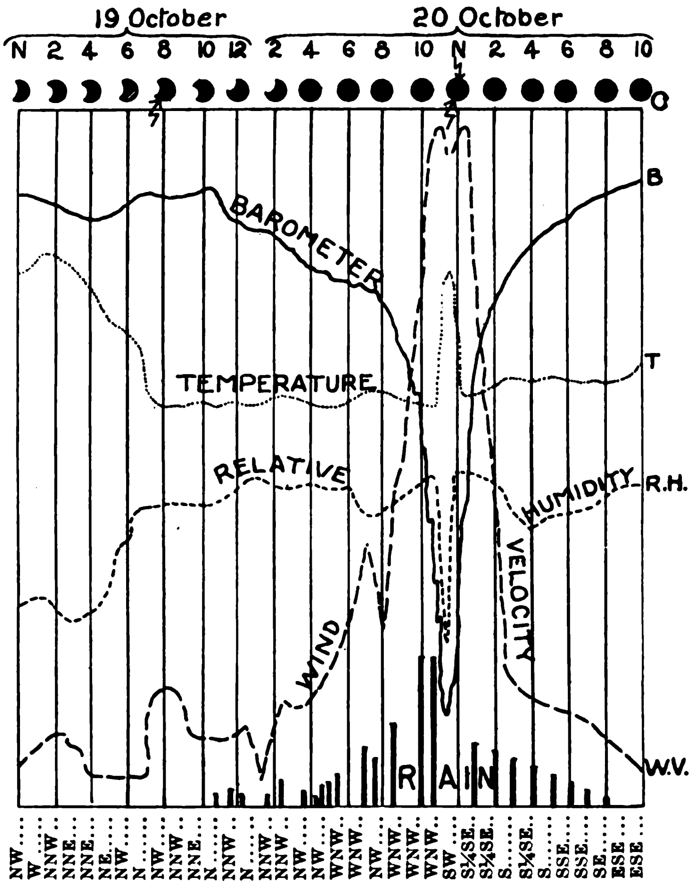


Fig. 738. Changes in the various meteorological elements at Manila, P. I., during passage of hurricane of October 19 and 20, 1882. (After Wagner.)

The paths of these tropical cyclones occupy rather narrow zones of constant position on the earth's surface. Fig. 739 shows the paths of a number of cyclones plotted on the same map, from which it is evident that the storms in general start somewhere in the doldrums, move at first westward, then northwestward until, reaching the apex of their paths, they turn sharply northward and northeastward, finally disappearing somewhere in the area of tropical high pressure or gradually dying out in the northern latitudes over the oceans. Since these storms follow a rather definite parabolic course, and themselves consist of a very definite whirl of winds, it is now possible to frame rules of safety for the guidance of mariners who happen to get in the way of one. These rules may be briefly stated as follows: First, do not run before the wind, especially if the vessel is on the right of the storm track (left in the southern hemisphere); second, trim the sails so as to take the wind on the starboard beam or quarter.

There are five regions of the earth's surface where tropical cyclones are most frequent, namely, in the vicinity of the West Indies, in the China seas, in the Bay of Bengal, in the Arabian sea and in the southern Indian ocean. The accompanying table shows the percentage of the total number of cyclones occurring each month in each of these regions, and the total number observed during periods of different lengths:

TABLE OF FREQUENCY OF TROPICAL CYCLONES.

Regions	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Totals
	%	%	%	%	%	%	%	%	%	%	%	%	
West Indies cyclones (1493–1855) .	1	2	3	2	1	3	12	27	22	20	5	2	355
West Indies cyclones (1878–1900) .	0	0	0	0	1	3	3	26	26	34	4	3	95
Typhoons, China seas	0	0	0	2	4	10	19	18	23	13	9	2	244
Bay of Bengal	2	0	2	8	18	9	3	3	5	27	16	8	139
Arabian sea	6	0	4	13	19	21	1	0	2	11	21	2	53
Southern Indian ocean	22	19	18	15	6	1	0	0	0	1	8	10	328
Western South Pacific	30	18	28	6	1	0	0	0	1	1	3	12	125

It is a significant fact as bearing on the origin of these storms, that the above table does not show any tropical cyclones in the south Atlantic ocean. This seems to be due to the fact that the south Atlantic ocean is never invaded by the belt of equatorial calms called the doldrums. The table shows that the months having the largest number of cyclones are those when the doldrums are farthest from the equator, while the months having the fewest cyclones are those when the doldrums lie close to the equator.

The origin of tropical storms, worked out with careful reference to the peculiar conditions of temperature, atmospheric moisture and geographical position, seems to be undoubtedly a characteristic of this doldrum belt. The storms, if they consist of an ascending spiral whirlpool, evidently could not be formed in the zone of steadily moving air which forms the trade-winds, but could develop wherever highly heated air near the surface has an opportunity to rise rapidly and thus initiate the basal inflow of air that may be set into a right- or left-handed whirl by the deflecting force of the rotating earth. When the doldrums lie close to the equator, any convectional currents that may arise in them are least likely to be converted into spiral inflowing whirls, because the deflective force of the earth is then at its weakest. But when in August and September the doldrums reach their maximum northern position such convectional currents are subject to a stronger deflective force and may conceivably unite to form an ascending vortex. The vortex thus started tends to move gradually toward the west, following the drift of the surface air controlled by the near-by trade-winds. As the vortex increases in strength, it passes beyond the limits of the doldrums and gradually becomes caught in the northwestward drifting air that flows from the eastern coast of all northern continents, toward the northeast. The absence of all tropical cyclones in the south Atlantic and their presence in the southern Indian ocean is thus evidently explained by the fact that the doldrums never migrate far enough southward over the south Atlantic to come within the influence of the stronger left-hand deflecting force of the southern hemisphere, while in the southern Indian ocean the doldrums are found to attain higher southern latitudes.

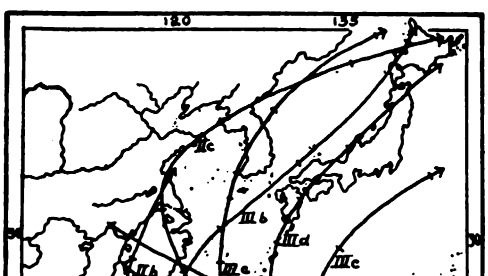


Fig. 739. Average typhoon tracks. Average progress per 24 hours indicated by short cross lines. (After Bartholomew.)

Extra-tropical cyclones.—Extra-tropical cyclones are so called because they originate in the temperate latitudes of both hemispheres outside the zone of the tropics. In many ways they resemble the tropical cyclones just described. Thus, they are characterized by a system of spirally inflowing winds at the earth's surface and of spirally outflowing winds overhead. They also vary in intensity with the degree of depression of the pressure at their centers. In their case, also, the central low pressure area is no doubt in part the effect of the centrifugal forces of the revolving winds, but to a less degree than in the case of the tropical cyclones. Extra-tropical cyclones are also of frequent and more or less regular occurrence and greatly disturb the regular flow of the westerly winds. They have a general eastward direction of travel, following the great circumpolar current of the westerly winds, but their paths follow less well-defined routes than do the paths of the tropical cyclones. Fig. 740 shows the paths of a number of these extra-tropical cyclones.

The extra-tropical cyclones differ from the tropical cyclones chiefly in that the area of low pressure determining the storm-center is of much greater extent than in the latter class of storms, that the winds accompanying the cyclone are much less violent, and that the contrast between the low pressure at the center and the surrounding higher

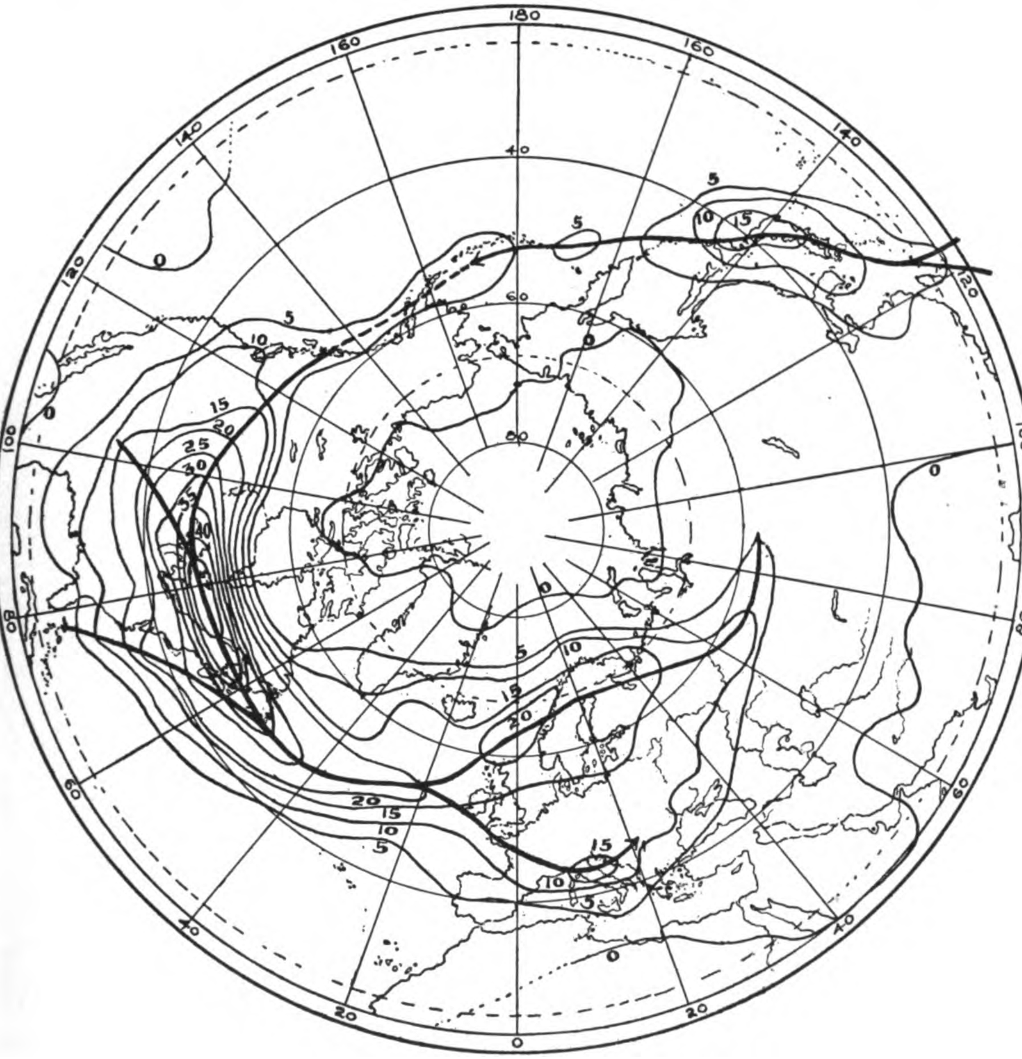


Fig. 740. Annual storm tracks and frequency of extra-tropical cyclones. (After Bartholomew.)

pressure is much weaker. These two classes of cyclones also differ in the arrangement of the isobars about the storm-centers, the extra-tropical cyclones showing a less well-defined circular arrangement, being rather often elongated into an oval form with the longer axis of the oval directed northeast, at least over the eastern United States. The paths most frequently followed by the extra-tropical cyclones as they cross the United States are shown in the small map presented in Fig. 741. On this map the arrows show the direction in which the storms move. The path lettered F is the one usually followed by the tropical cyclones or hurricanes, and shows the characteristic recurving northward and northeastward which Fig. 739 has already brought out. Most of the storms that cross the United States follow the paths B, C or D, which unite in the vicinity of the Great Lakes to form the great trunk line A. Most of the storms that pass off along A reach the Great Lakes by the path B, and practically all of the violent extra-tropical cyclones of the United States come along this path. Storms that enter the United States from the south, following paths D and E, are much less frequent and nearly always of relatively mild character. Occasionally a tropical cyclone reaches out farther westward than the path F and does not recurve northward until somewhere near the beginning of the path E. The great Galveston hurricane was one of these rare storms that failed to turn north along F, and ran far enough westward to strike the Texas coast before it turned up along the path E.

Since the establishment of a well-distributed net of observers over Europe and the American continent, it has become possible to map these extra-tropical cyclones with considerable accuracy, and to follow their positions and changes from day to day, and even from hour to hour. As a result of these observations, it is possible to prepare tables showing the rates at which the storm-centers move; such a table is given below:

Average Velocity of Progression of Extra-Tropical Cyclones. Miles per Hour.

	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Average
United States (Lat. 25–45)	33.8	34.2	31.5	27.5	25.5	24.4	24.6	22.6	24.7	27.6	29.9	33.4	28.4
Europe (Lat. 40–60)	17.4	18.0	17.5	16.2	14.7	15.8	14.2	14.0	17.3	19.0	18.6	17.9	16.7

The table shows the average velocity of the center of the storm in miles per hour in different months of the year; and from this table it is apparent that the storms move faster in winter than in summer, corresponding to the winter increase in the velocity of the circumpolar winds. It is now a familiar fact, also, that the extra-tropical cyclones attain their greatest strength in the winter months, while they almost fade into non-recognizable centers of low pressure during the summer. These great winter storms are the most important because of the dangers that they bring to shipping, and even to land travel. In this connection it will be interesting to study Fig. 742, which illustrates graphically the relative frequency with which fast-moving cyclones visited different parts of the United States during the period from 1893 to 1902. It is made apparent, from this map, that a small region in Canada just northeast of Lake Huron is most frequently visited by these fast-moving and severe cyclones. The region of the Great Lakes is indeed the one in general most frequented by these storms, whether mild or severe.

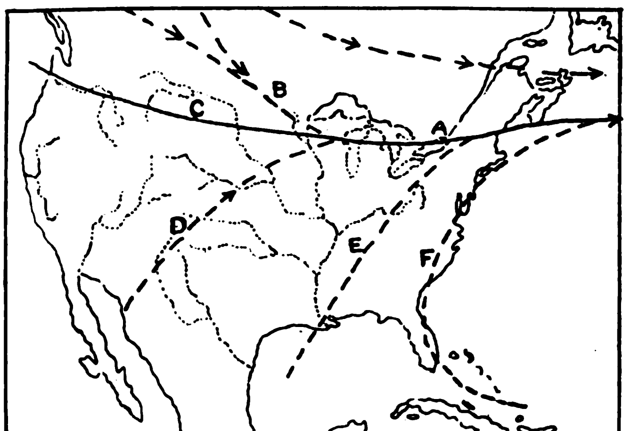


Fig. 741. Paths of cyclone centers across the United States. Path F usually followed by tropical cyclones or hurricanes. Most storms crossing the United States follow the paths B, C, D, which unite in the vicinity of the Great Lakes to form the main trunk A.

Characteristic weather of a cyclone.—The general shape of an extra-tropical cyclone, together with the distribution of rain and clouds about the storm-center, winds and temperature, is shown in Fig. 743.

This figure has been constructed by making a composite map from a large number of separate storms as shown on the daily weather maps. The solid oval lines represent isobars, and show the characteristic oval outline of these extra-tropical cyclones. The path of the storm-center is indicated by the line lettered AC, while the paths of the winds blowing about the storm are shown by the arrows. The arrows in this figure, however, indicate the directions of the winds at the earth's surface, while subsequent figures will show the direction of the winds at different levels above the earth's surface as it has been determined by observing the movements of the clouds. The wind directions about extra-tropical cyclones are seen to correspond in a broad way with those about the tropical cyclones. The average direction of the wind of the southern and eastern quadrants of the storm is from the south and southwest; the winds in the northeast quadrant are from the southeast and from the east; the winds to the north of the storm-center blow from the northeast and the north, while the northwest quadrant is characterized by northwest and west-northwest winds. The shaded parts of the figure, representing the distribution of cloud and rain or snow about the center of the storm, show that most of the cloud lies in the northeast, southeast and south quadrants. The latter two quadrants of the storm are those in which the inflowing winds are bringing the moisture that goes to form the clouds and to supply the rain. The westerly quadrants, especially the northwest quadrant of the storm, are accompanied by the least cloud and the most clear sky; the winds of this quadrant bring in little or no moisture to the storm-center, but rather tend to dissolve the clouds that have been formed in the front quadrants.

As such a storm-center approaches any region, it is heralded by lofty, feathery clouds (cirrus) that seem to spread eastward across the sky from the higher layers above the approaching storm-center. These clouds sometimes outrun the true

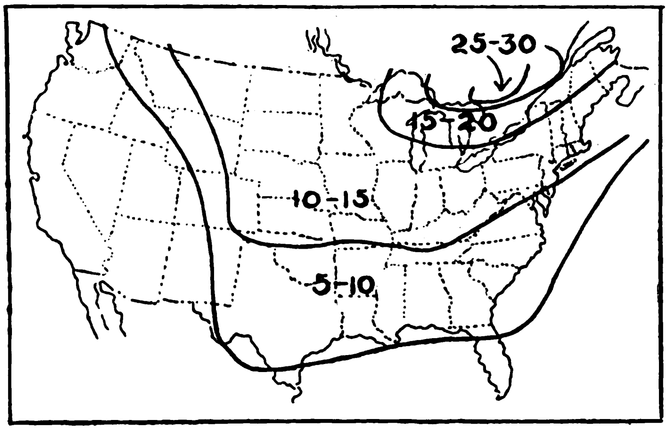


Fig. 742. Geographical distribution of fast-moving cyclones (1893-1902). (After Hanslik.) Number of tracks per 5° square.

storm-center by several days, and are always a reliable indication of the approach of a center of low pressure. They evidently indicate the overhead spiral outflow of air from the storm-center just as in the case of the tropical cyclones already described. The nearer approach of the center of low pressure is shown by a gradual clouding over with heavy low-lying clouds, also coming from some westerly point, and the clouds soon begin to give up rain or snow, depending on the time of the year. Accompanying these changes in the state of the sky, the wind also undergoes a characteristic shifting of direction. If the observer chances to be located directly in the path of the storm, the lofty, feathery clouds, which are clearly moving from west to east, will be seen to be accompanied by a surface wind blowing from the southeast. As the area of forming lower clouds approaches, the wind shifts to the east and to the northeast, where it remains during the passage of the rainy center. At the same time, the temperature, as shown by the curving dotted lines, or isotherms, in Fig. 743, has gradually risen during the approach of the storm and remains appreciably warmer until the center of the storm has arrived. But just before this occurs, as the illustration shows, the wind draws more and more from the north, bringing in air from higher and colder latitudes; consequently the temperature begins to fall and continues to fall by reason of the increasing influx of cold air until the rain and clouds have cleared away. The temperature curve of Figs. 721 and 722 also shows the influence of the passage of a cyclone. As the storm-center passes beyond the observer, the wind shifts to the north-northwest and the northwest, the air becomes appreciably drier, the rain ceases to fall, and it soon becomes evident that the rain-bearing clouds are no longer overloaded with moisture but are beginning to dissolve. As the storm-center finally recedes, the strong northwest or west-northwest wind coming in behind the storm brings a great current of cold dry air, which it is clearly seen is actually dissolving the rear guard of the storm-center. As Fig. 743 indicates, a greater interval elapses between the first rainfall and the arrival of the storm-center than elapses after the passage of the storm-center until the last rain falls and the clouds finally clear away.

This unsymmetrical distribution of cloud and rain about the storm-center is rather simple of explanation. The winds of the eastern and northeastern quadrants are drawn in toward the storm-center from regions lying far to the south and southwest of the storm. Consequently, they are bringing warm air capable of carrying considerable quantities of moisture. As these warm, moisture-laden southerly winds approach the center and are forced to rise to higher levels by the underrunning cooler winds that they meet, the air must expand and cool, thus causing the moisture to con-

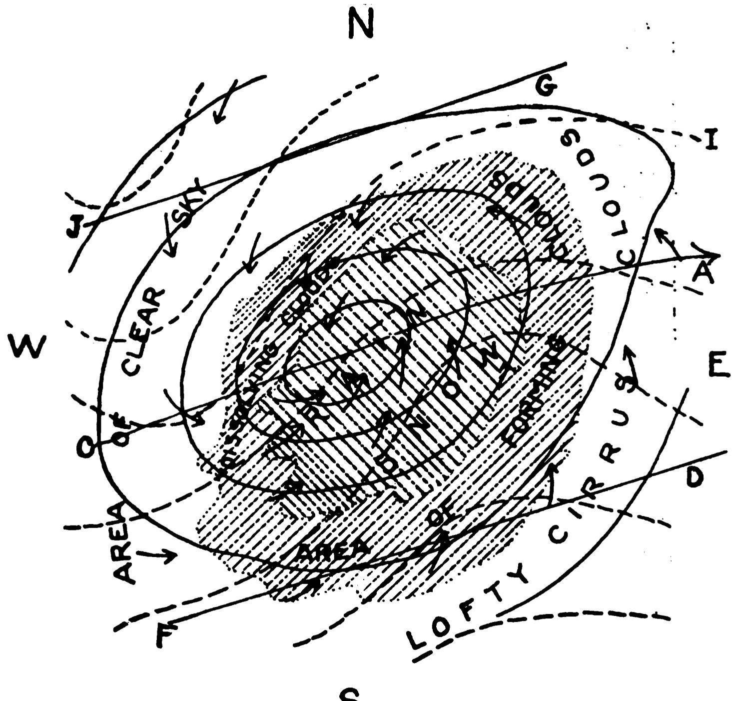


Fig. 743. An ideal representation of the distribution of the various weather elements about a well-developed center of low pressure. A C shows path of storm-center. Arrows show path of winds blowing about the storm at the earth's surface. The shaded parts represent the distribution of clouds and rain or snow about the storm-center. (After Davis.)

dense into clouds and rain. On the other hand, the air gathered in the northwest and southwest quadrants of the storm is brought in from regions lying far to the north and northwest of the storm. By the time the storm-center reaches the region of the Great Lakes, the winds of the northwestern quadrant are bringing to it air that has passed over broad expanses of cold lands, so that its temperature is much reduced below that of the winds blowing in the southeastern and eastern quadrant. As we shall see shortly, these northwestern winds are also descending currents, and, therefore, drier at a great distance from the storm-center, while, at the same time, they become cooled to very low temperatures in passing over the cold expanses of arctic lands.

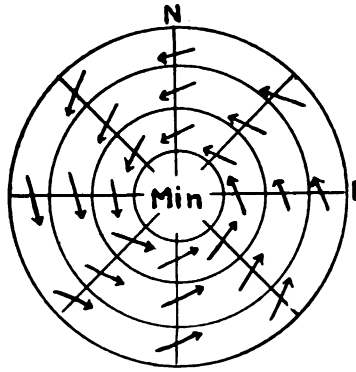


Fig. 744. Surface winds about center of low pressure.

As will be seen from Fig. 743, the changes in wind direction and in temperature depend on the position of the observer with reference to the path of the storm-center. The changes above outlined for an observer stationed directly in the path of the storm, are subject to slight modifications if he chances to be situated to the north of the center, i.e., along the line GJ, or to the south of the center, on the line DF. As soon as one is familiar with the distribution of weather about a low-pressure center, it becomes an easy matter to decide on which side an approaching storm will pass, and also to predict in a general way the weather changes one may expect for the next few hours. Of course, the rate at which these weather changes take place will depend also, in part, on the rate at which the storm travels, and while the average rate of movement of these storm-centers is shown in the table above given, yet individual storms display a considerable amount of individuality in this respect. Sometimes a storm will remain almost stationary for a number of hours, or even a day or two, at quite unexpected points. In such cases, the professional as well as the amateur weather predictor is certain to make miscalculations, since he has no way of telling at what point in its path such a halt will be made or how long it will persist.

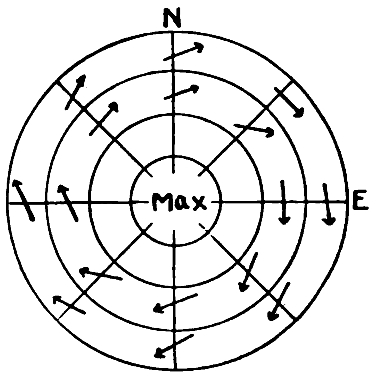


Fig. 747. Surface winds about a center of high pressure.

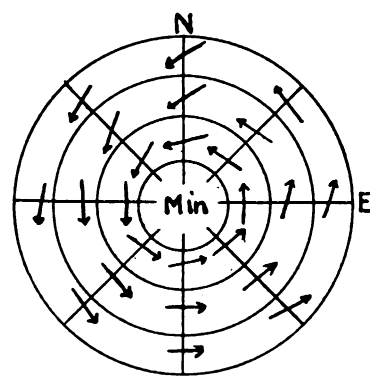


Fig. 745. Movement of lower clouds about center of low pressure.

The center of low pressure forming an extra-tropical cyclone is always associated with one or two centers of high pressure. In Figs. 744, 745, 746, 747 and 748, is contrasted the atmospheric circulation about centers of low pressure and high pressure. Figs. 744 to 746 show the wind-movement at three different levels about the center of low pressure. The wind directions as shown by the arrows have been determined from a large number of observations of the cloud movements at several levels in the atmosphere over broad areas of the northern hemisphere. A careful study of the first three figures shows that while the surface winds about the low pressure exhibit a well-marked right-hand deflection from the radial lines indicating the steepest barometric slopes toward the center, yet all the winds blow distinctly inward. Fig. 745, giving the direction of the lower clouds, shows that this right-hand deflection is of yet greater magnitude at a moderate elevation, so that the winds have an almost circular move-

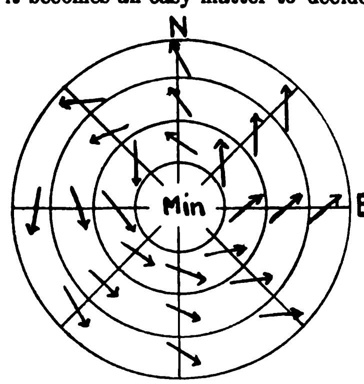


Fig. 746. Movement of high clouds about a center of low pressure in northern hemisphere.

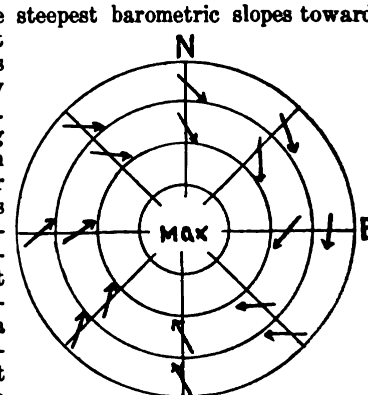


Fig. 748. Movement of high clouds about center of high pressure in northern hemisphere. (Figs. 744–748 after Hann.)

ment around the center and the inward component becomes almost nothing. The directions of the highest clouds over the center of low pressure (Fig. 746) indicate very distinctly a spiral movement away from the center of low pressure. When the three figures are thus taken together they make clear the whirling inflow of winds at the surface of the earth and the spiral outflow in the upper layers over the low pressure. We must conclude that the air is being drawn in and whirled upward about the storm-center. As a consequence it is being centrally elevated, made to rise to levels of lower pressure, thereby causing it to expand and cool. The storm-center is therefore characterized by growing clouds of moisture condensed from the ascending and cooling currents of air.

On the other hand, the directions of the winds about the center of high pressure show that the surface winds (Fig. 747) are moving spirally outward away from the center, while in the uppermost levels (Fig. 748) the winds are moving spirally inward toward the center. We can understand this condition only by supposing that around the center of high pressure we have the air moving in a descending spiral, fresh air being continually drawn in from the higher levels, where low temperature and small amounts of moisture prevail, to supply the constantly outflowing mass of air at the surface of the earth. Since the air is thus forced to descend around the centers of high pressure, the winds blowing out from them at the surface of the earth are composed of air that has descended into levels of greater pressure. The resulting compression to which the cold, dry air from above is thus subjected causes its temperature to rise, and it must therefore become relatively better able to hold moisture in the form of gas. The winds blowing outward from the center of high pressure must therefore be composed of air that has been constantly increasing in dryness and in temperature, and hence, the few clouds that may float in the vicinity of such a region of high pressure tend to become dissolved; so that these centers of high pressure are characterized by clear skies and dry winds that are still very cold, since they come from great heights in the atmosphere, although they are relatively much warmer than the average temperature of the air at their source. The central part of an area of high pressure is characterized by very light, uncertain winds, and the prevailingly clear sky permits the diurnal warming of the earth and lower air, a condition that is not possible in the prevailingly cloudy area of the low-pressure center.

Occasional winds associated with centers of high or low pressure.

When the temporary distribution of centers of high and low pressure bears special relations to the larger topographical features of certain parts of the earth's surface, characteristic and peculiar winds arise. These may be grouped into two large classes, namely, hot, dry winds and cold winds. One of the best known of these winds is characteristically developed in the northern valleys of the Alps and over the eastern base of the Rocky mountains in the United States and Canada. This wind is very dry and hot, and occurs in its best developed form in the winter months, when a well-marked center of low pressure located, e. g., north of the Alps, compels the air, in its course toward the center

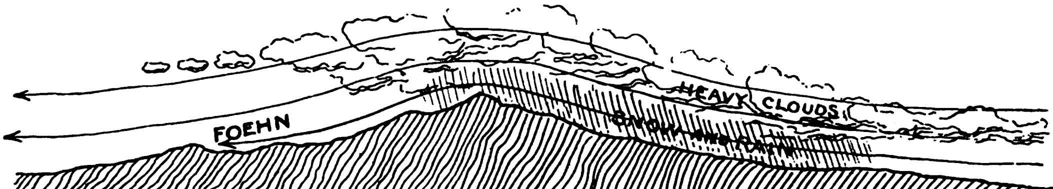


Fig. 749. Illustration of conditions when a foehn wind arises. How mountain ranges cause heavy precipitation. (After Davis, Elementary Meteorology, Ginn & Co., Boston.)

of the low, to descend rapidly from great elevations. In this case, the high pressure south of the Alps and the low pressure north of the same compel the wind to pass across the ranges of these mountains, so that, after losing much of the moisture in its climb up the southern slopes, its rapid descent to the piedmont region to the north is accompanied by a rapid increase in temperature of the already moderately dry air. Thus the northward sloping valleys are invaded by strong northward moving currents of rapidly warming and drying air. The hot winds thus produced are known as the foehn, and they cause the snow to disappear rapidly from the valleys, not by melting it, but by evaporation. Usually, the foehn is so dry that the thatched roofs of the Alpine huts become like tinder and many disastrous village fires have occurred while such a wind was blowing. In North America a similar wind results when a center of low pressure is located east of the Rocky mountains, drawing the upper air from the summits of that range rapidly downward and across the plains at their eastward base. Here, again, the compulsory rapid descent of the air causes an increase in temperature and in dryness and produces changes on the objects exposed to it similar to the changes observed in the Swiss valleys. Natives call this wind the chinook. When the chinook blows over snow-covered grounds it also dries off the covering and makes it possible for the cattle to secure food in the winter, which, under other conditions, they would not be able to secure. Other regions besides the North American and Swiss localities are characterized by these foehn-like winds; even the western coast of Greenland is occasionally visited by them. In New Zealand they occur as northwesters blowing across the Canterbury plains, and in the Argentine Republic at the eastern base of the Andes. The relations between wind direction and an elevated mountain range when the foehn originates, and the heavy precipitation on the south side of the mountain, are shown by Fig. 749.

The weather known in the United States and Canada under the name of "cold-wave" follows after the passage of a well-marked center of low pressure during the winter, and is most typically developed when the inflow to the low center is strengthened by a marked area of high pressure west or northwest of it. The strong current of cold air that is called a cold-wave is nothing more than a well-accentuated form of the inflow of air in the northwestern quadrant of a low pressure center, but the velocity has been increased by reason of the contrast in pressure above described, and its temperature has been greatly lowered by radiation over the broad expanse of country already at a low temperature by reason of its snow cover as well as its high latitude. In eastern North America the cold-wave current has free sweep over broad plains without interruption by strong mountain ranges. If this stream of cold air, with its high velocity, carries with it a blinding cloud of snow and a temperature well below freezing, it is called a blizzard. The same phenomena are observed in Europe, but rarely or never attain the same degree of development as is permitted by the broader and smoother stretches of land in North America, except when the storms have passed into Russia and Siberia, where the topographical conditions more closely resemble those of North America. The mistral of France corresponds in a mild way to the cold-wave, while the buran of Russia corresponds almost exactly to the blizzard. The limited land areas characteristic of the high latitudes of the southern hemisphere prevent the extremely low temperatures characteristic of North America and Eurasia, but cold winds corresponding in genesis to the cold-waves, and known as pampero, are observed in the Argentine Republic.

While a cold-wave may be prevailing on the western side of a strong winter center of low pressure, a very moist and oppressive warm wind often prevails on the eastern front of the same low center. As already pointed out in discussing the distribution of weather about the center of low pressure, the air in the front and northeast quadrant of such a center is being brought in from southern latitudes where it has a relatively high temperature and often carries considerable moisture. When such a wind appears in the average cold winter it causes a season of unpleasantly high, moist temperature, which is sometimes called in North America a "warm-wave." In the summer such a wind may be dry as well as hot, because it is derived from regions which, at that season, are dry as well as warm. In America there is no distinctive name for this wind. The same phenomenon is known in Italy under the name of sirocco, and we might well adopt this name into our meteorological vocabulary as a generic term. Similar winds, but of course blowing from the north, have been observed in the southern hemisphere, particularly in Australia.

Thunder-storms.

Thunder and lightning accompany various disturbances of the atmosphere, one of which is usually referred to by the term thunder-storm. The great mass of steam rushing off from any volcanic eruptions, and the resulting piles of cloud and rain, are often accompanied by lightning and thunder; so also are the tropical hurricanes already referred to; and mild disturbances accompanied by a light fall of rain in the spring and early summer show the same phenomena. The typical thunder-storm, however, seems to be peculiar to itself. It is characterized by a peculiar outrushing squall or gust of wind just before the heavy rain begins. The first stages of its formation are marked by the gathering and upbuilding of towering, snowy, white cumulus clouds that are often called thunder-heads. The storm has a certain linear extent or front which moves more or less parallel to itself across considerable stretches of country. The approach of a summer thunder-storm is indicated by a higher forerunning layer of cirro-stratus cloud, which rapidly becomes thicker toward the center of the storm. As the great rain-bearing cloud approaches, the upper layers of cloud sometimes are seen to be slowly descending and dissolving along their under surface. While the storm-center is still at some distance, the surface winds are all inward toward the center, but the upper cirro-stratus forerunners can frequently be seen to be moving in the opposite direction under the influence of upper outward-blowing currents. On the approach of the center of the disturbance, the characteristic thunder-heads, with their rounded tops and their level clear-cut base, may be seen with the rain falling from their lower levels, and the indraft air current gives place to a strong out-rushing wind or squall of short duration, which precedes the heavy rain of the storm. This outrushing wind has a sensibly lower temperature than the hot, stagnant air that prevailed before the storm approached, and is frequently strong enough to brush up the dust of the dry earth into a blinding cloud which it drives before it. The first few drops of rain generally accompany the first strong near peals of thunder, and the heavy downpour is accompanied by the most violent electric discharges. At the same time, the storm is moving rapidly across the point of observation, and usually within half an hour the rain slackens and the clouds break on the western horizon, showing the blue sky. Here, again, as in case of the large cyclonic disturbances, the storm clears away after the heaviest rain in a much shorter space of time than was required for its center to approach, due to the fact that the rear of the storm is much smaller than the front. The barometer falls slowly as the thunder-storm approaches, shows a sudden slight rise as the wind-squall arrives; then, as the wind weakens, after standing steady for a short while, gradually rises again as the storm clears away. The humidity is usually moderately high before the storm; it generally rises to its maximum during the heavy downpour and then decreases gradually below its previous degree.

Simultaneous observations on the occurrence of thunder-storms, over areas equal in extent to two or three states, show that the summer thunder-storms, while of limited extent, yet may traverse a path of not inconsiderable length. Fig. 750 shows the successive positions of the front of a thunder-storm that traversed the entire length of the state of Massachusetts.

Thunder-storms characteristically occur in warm regions during the warm season, when the vertical change in temperature is more rapid than during the cold season or in colder regions. They are evidently due to rising currents in the atmosphere which are bringing masses of warm, moist air rapidly into higher levels, thus permitting simultaneously expansion, cooling and condensation of the moisture. The possible beginnings of a thunder-storm may be observed on a summer day when white cumulus thunder-heads are beginning to form. These clouds often show in a most convincing manner the presence of ascending currents of air in their midst, for they seem to be boiling over and puffing up at the top under the compelling action of hot air rising from below. The origin of the electric phenomena which accompany thunder-storms has not been satisfactorily explained. The frequent occurrence of hail with summer thunder-storms is taken as a further indication of the action of the currents ascending and descending within the sphere of disturbance.

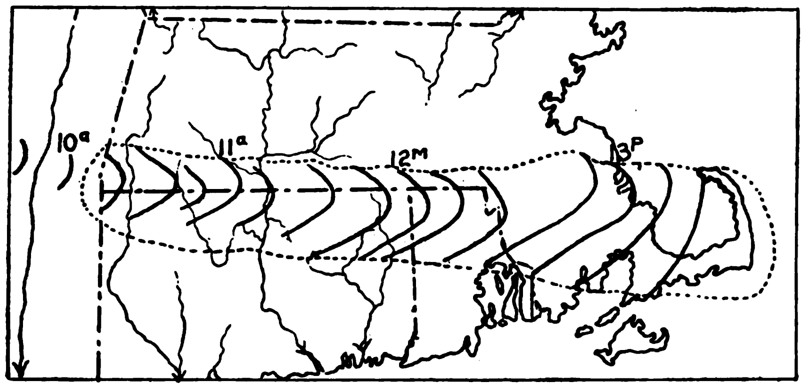


Fig. 750. Path of a thunder-storm from Hudson river to Cape Cod. The curved lines show successive positions of its axis at intervals of fifteen minutes. The area of rainfall is enclosed by a dotted line. (After Davis.)

Thunder-storms are common in the doldrums or about the equator, where they generally occur in the afternoon or early evening, and are accompanied by very heavy rains. The most violent equatorial thunder-storms are met with near the lands under the equator, especially in equatorial Africa and over the Atlantic just west of that continent. They are of short duration, although of extreme violence, and their passage is succeeded by a return of the characteristic calms of the torrid zone. In South America violent thunder-storms characterize the summer season in the Argentine Republic and Uruguay. Sometimes the valley breezes ascending the slopes of mountainous regions become strong enough during the season to build up thunder-heads above the summits of the mountains, so that mountainous regions also become breeders of thunder-storms. Thunder-storms generally occur in their best developed forms in the southeastern quadrant of an extra-tropical cyclone, but are more or less independent of the clouds and rain accompanying the latter and are removed several hundred miles from the low center. They move in general easterly directions in temperate latitudes, thus accompanying the low center in its general easterly movement. They are particularly characteristic of those centers of low pressure where the winds around the southern part of the cyclone meet in such a way as to bring the dry cool winds of the western half into sharp and close contrast with the warm moist winds of the eastern half. Sometimes it would appear as if the cool winds push in under the warm moist currents, causing them to rise and roll over on themselves, thus developing great thunder-storm clouds. This could occur, however, only when there is a strong contrast in the temperature and density of the two winds.

Tornadoes.

Tornadoes are revolving storms of great energy but of very small diameter, that are generally formed within the area of disturbance belonging to a thunder-storm. They present the appearance of a long funnel-shaped cloud hung from the bottom of a great mass of thunder-heads. This funnel is the outward and visible evidence of a mass of violently ascending and whirling air that advances generally eastward or northeastward at a rate of twenty to forty miles an hour. Its diameter may reach a few hundred feet, but it is always greater above than at its lowest point or at the earth's surface. The violent motion of the air gives rise to a deafening roar, and the velocity of the wind in its whirling vortex is so great that everything that comes within its limited reach is destroyed. A single one of these whirls may live for half an hour or an hour, and its path across the country, twenty miles or more long and usually less than a quarter of a mile in width, is marked by complete devastation. If such a tornado occurs over the ocean, it is called a waterspout and the apparently descending cone or cloud is frequently met by an ascending cone formed by the water caught up from the surface of the ocean.

The tornado originates through the vertical currents set up in a cloudy atmosphere under strong heating action of the sunshine. These conditions favoring ordinary thunder-storms are characteristically reinforced in the case of tornadoes by the bringing in of masses of air at different temperatures and humidity from perhaps widely separated regions, due to the peculiar conditions that accompany great extra-tropical cyclones. These conditions, as already stated, give rise in a general way to a broad thunder-storm, while within the thunder-storm itself strong local updrafts seem to rise, which contain the beginning of the tornado vortex. This view is supported by the observed greater frequency of the association of tornadoes with thunder-storms of great activity, having unusually heavy rain and very frequently accompanied by hail-storms. There is no known definite connection between electrical or other agencies and the origin of these tornadoes or of the thunder-storms. On the other hand, convectional action is always present in both and offers a presumably sufficient explanation of the phenomena they present.

The most interesting and important feature of the tornado is the violently whirling mass of air whose location is marked by the funnel-shaped cloud. This mass of air whirling around the axis of the funnel does not remain at a constant distance from the axis, but is rapidly approaching it. According to a well-known law in physics, the linear velocity of the wind increases very rapidly toward the axis of this vortex or whirl; consequently the velocity is greatest for a short distance about the funnel cloud. In all cases where the direction of the whirl of the tornado has been observed in the northern hemisphere, either by direct watching of the cloud or by a later study of objects overturned by the winds, it has been found that the vortex is whirling from right to left, corresponding to the general direction of rotation of the winds about the cyclonic centers of low pressure and in tropical hurricanes. Evidently the tornado is subject to the same deflective influence that so characteristically controls the winds of the cyclone. Formed as the tornado vortex is, within the influence of the great cyclonic whirl, it does but obey another observed law of physics when it rotates in the same direction as the greater whirl. The tornado vortex usually moves in an eastern or northeastern direction, sometimes toward the southeast, but seldom in any other direction. It may pass any point within less than a minute or may endure for half an hour to an hour. Since the conditions favorable to one tornado are always favorable to the forming of a number, it is probable that when tornado paths of a length greater than fifty miles have been reported, two or more whirls forming one after another have been confused with one another. The passage of a tornado vortex is accompanied by a gradual fall of the barometer interrupted by a sudden drop to extremely low pressure at the moment of passage of the tornado axis. It has been reported from some tornadoes that corks have been blown from empty bottles, and a number of cases are known in which walls or windows fell outward as if the air within the building had expanded and burst them out at the moment of passage of the tornado.

An approaching tornado may be avoided if one can remain cool enough to take a path that will carry him away from the center of it. If the tornado is approaching in such a way as to show that it will pass near the observer but somewhat to one side or the other, he should run in a direction at right angles to the path of the storm, taking care not to cross its track in so doing. If he can gain a distance of five hundred feet before its arrival, he may be certain of reaching comparative safety. If the tornado is coming directly toward the observer, it is better to run toward the northern side of its path, since its whirling winds are somewhat weaker on that side. Tornadoes occur most frequently in the Mississippi valley during the warm months that are characterized by the greatest number of thunder-storms. They are generally most frequent in the southern or southeastern quadrant of an area of low pressure, and the region of their occurrence progresses with that center.

Section VI. Atmospheric Moisture

Many phenomena of every-day life show us that there is more or less moisture present in the earth's atmosphere at all times. The clouds floating in the air, the rain and snow that fall from them, and the fogs at the earth's surface, are familiar evidences of the presence of aerial moisture. There is always some moisture present in an invisible gaseous state, also, that is not so readily perceived and yet produces familiar effects which indicate its presence if their meaning is considered. Thus the familiar oppressive feeling characteristic of summer weather is due to the presence in the air of a large amount of moisture that hinders evaporation from the body and the consequent cooling of the same. The drops of water that sometimes form on the outside of a vessel containing any cold substance are popularly believed to be moisture that has passed through the walls of the vessel; but in fact the moisture has simply been condensed from the surrounding atmosphere by reason of the low temperature at which the vessel is maintained by its cold contents. This phenomenon is often used to detect the presence of moisture in the atmosphere at any time, the only requirement being that the temperature of the vessel be brought low enough to cause the moisture to condense on it in the form of dew.

Source.

The chief source of all atmospheric moisture is the great ocean covering three-fourths of the earth's surface, while large inland bodies of water form important secondary centers of contribution for the air in their immediate vicinity. The network of rivers distributed over the lands, the smaller lakes, and especially the covering of vegetation of forest and field, also furnish some of the moisture; and in the extensive forest regions of the tropics or the broad, moss-covered tundra of the arctic regions, vegetation forms an important source. At all times and temperatures, water, snow and ice are being converted into the gaseous state, known technically as water vapor. The chief control of the rate of evaporation is temperature, an increase in temperature always being accompanied by an increase in evaporation. The wind, however, is also an important factor in determining the amount and rate because it removes from the evaporating surface the layer of moisture-laden air, permitting drier air to take its place, and thus maintains the evaporation or even increases its rate. Other things being equal, evaporation goes on most rapidly from surfaces of fresh water. However, the high temperatures of the tropical and subtropical seas combine with the extent of their surface to make these bodies of water the chief sources of atmospheric moisture. The average yearly evaporation from the surfaces of the tropical oceans amounts to a layer of water 63.8 inches in thickness. If this rate of evaporation were maintained unmodified from year to year, the surface of the tropical oceans would soon come to be extremely salty in contrast to the surface waters of higher latitudes. As a matter of fact, the surface waters of the tropics contain a less amount of salt than those of higher latitudes. This is due in large part to the very heavy rainfall of that region, which maintains a thin surface layer of sea water of lower density than the average.

Amount.

The presence of moisture in the atmosphere at all times being thus made evident, it becomes important to have some way of determining the amount present, since this factor has a very close bearing on the character of the weather in general. The simplest instrument invented for indicating the amount of moisture in the air is called the hair hygrometer. This instrument consists of a single thread of hair that has been washed clean of all fat in a bath of caustic alkali; one end is made fast to an immovable peg and the other passed around a drum, on which it is kept wrapped by the gentle pull of a spring or a light weight. Such a perfectly clean hair is peculiarly sensitive to the amount of moisture in the air, lengthening as it takes up moisture from a moist atmosphere and contracting as it gives off moisture to a drier atmosphere. Therefore, the drum about which the hair is wrapped will cause the attached pointer to move back and forth over a graduated dial, on which a perfectly divided scale indicates the varying condition of the atmosphere. The pointer may be made to record its motion by means of pen and ink on a moving strip of paper. Such an instrument is particularly useful at temperatures near or below freezing, when it is probably the most convenient means for measuring moisture. However, it is subject to errors due to unequal contraction and expansion; each hair must have its own peculiar scale constructed for it, and such an instrument must be frequently carefully compared with some other method less subject to uncontrollable errors.

The instrument in general use for determining the humidity of the atmosphere is called the psychrometer. This instrument, in its best form, consists of two exactly similar thermometers attached to the same piece of light board or metal, and the whole provided with a handle or cord for whirling it through the air. This instrument is illustrated by Fig. 751. One of the thermometers has its bulb smoothly covered with a piece of fine muslin, and just before taking the observation this muslin-covered bulb is thoroughly saturated with water; then the two thermometers are whirled in the free air, interrupting the whirling from time to time to read both thermometers. The evaporation of the moisture from the cloth about the wet thermometer bulb requires the latter to give up a certain amount of heat, thus reducing the temperature of that thermometer a definite amount. If the two thermometers are whirled at a steady rate, the wet-bulb thermometer will finally descend to a temperature below which it is not able to sink, while the dry-bulb thermometer will assume the true temperature of the air, and thus stand generally higher and never lower than the wet-bulb.

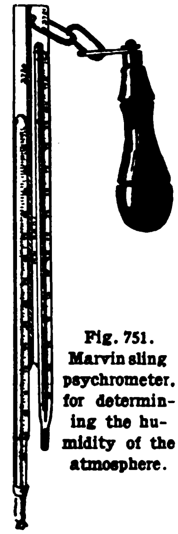


Fig. 751. Marvin sling psychrometer, for determining the humidity of the atmosphere.

The difference between the temperatures recorded by the two thermometers is not a constant one from time to time, but depends on the actual temperature of the atmosphere and the quantity of moisture contained in a unit volume of the same. Of two volumes of air both at the same temperature, that one containing the smallest actual amount of moisture will permit the greater amount of evaporation to take place from the cloth of the wet-bulb thermometer, thus causing it to register lower than it would when whirled through the volume of air containing the greater actual amount of moisture. This has been shown to be the case repeatedly by careful measurements of the actual amount of moisture, using some method by which all the moisture can be extracted from the air and weighed. Consequently it is possible to prepare tables showing the actual amount of moisture present in the air for any given temperature of the air and any given difference between the readings of the wet and dry bulbs.

The humidity of the atmosphere is thus indicated by the difference in temperature recorded by the wet- and dry-bulb thermometers. When the air contains a large amount of moisture it is said to have a high humidity, and when the amount of moisture is small the humidity is said to be low. The amount of moisture in the form of vapor which the air can contain depends on the pressure to which the air is subject and on the temperature of the air. Air that is very warm is able to maintain a larger quantity of moisture in the gaseous state than is the same volume of air when at a low temperature. If the air at a given temperature contains all the water vapor it is possible for it to hold at that temperature, it is said to be saturated, and

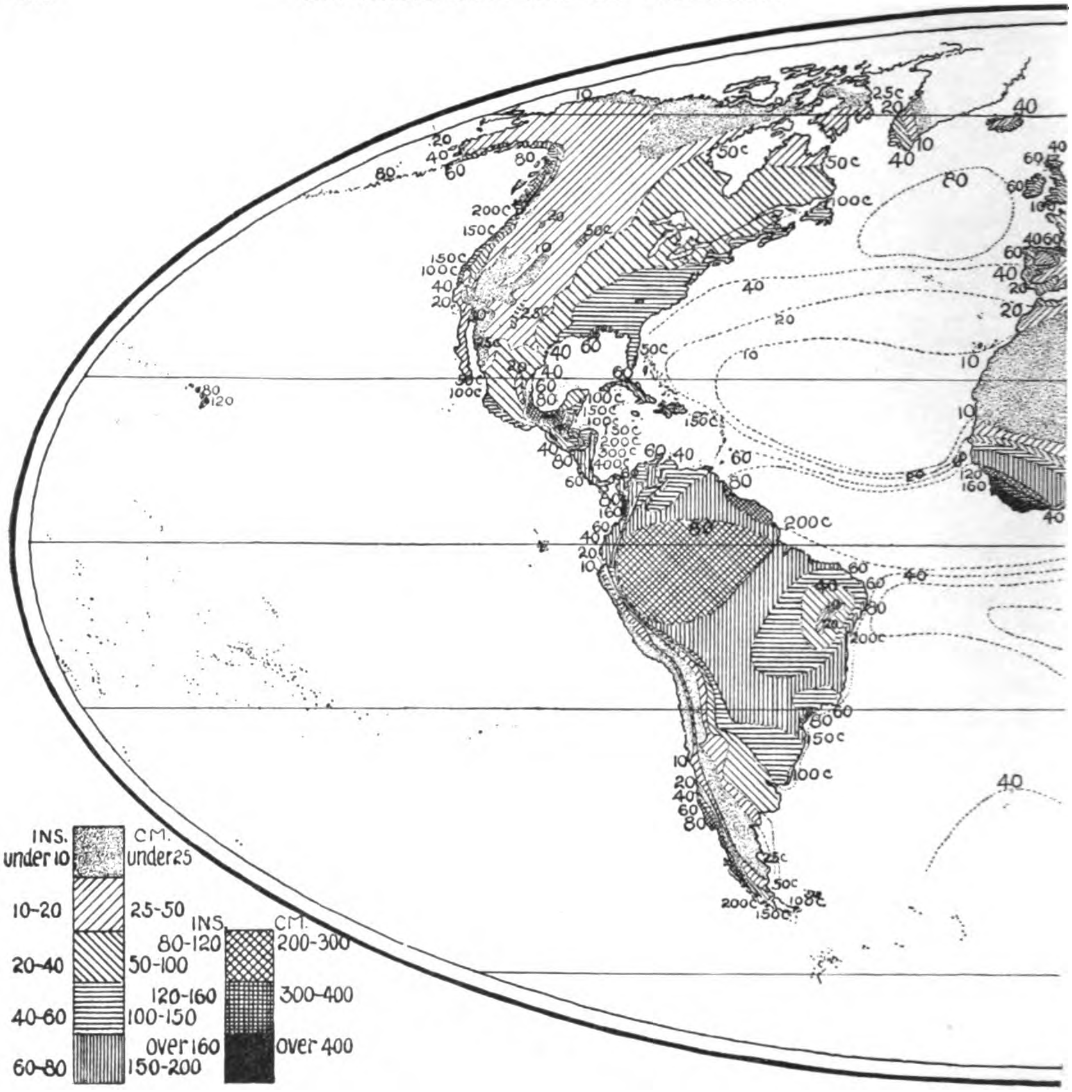
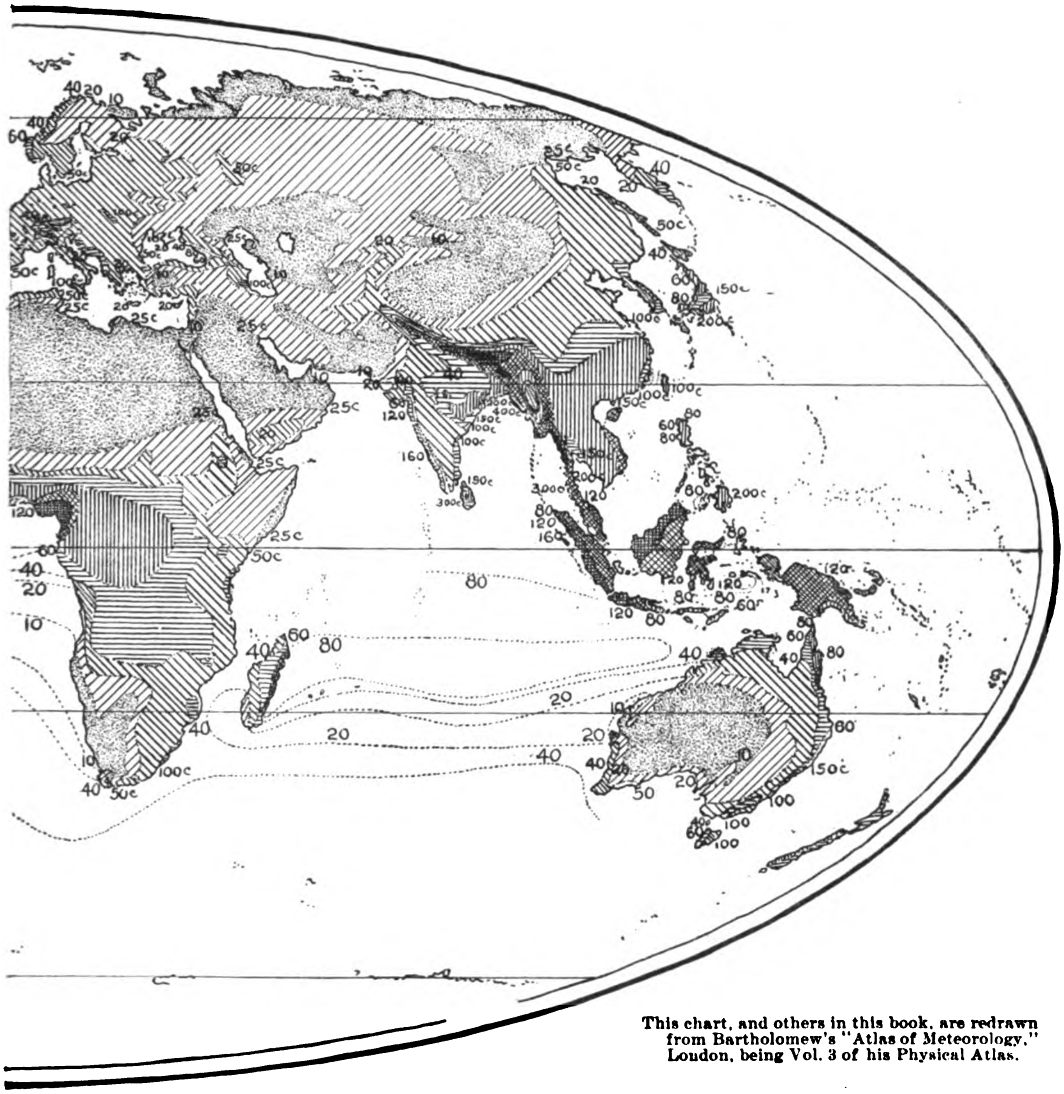


Fig. 752. Mean annual rainfall over the earth. The equatorial zone is region of heaviest rainfall; to the north and south

even a slight decrease in its temperature will then result in the condensation of a part of the vapor to the liquid state. Usually the atmosphere is not saturated, and the amount of evaporation that can take place from exposed surfaces of water depends on the degree of saturation. We are rarely interested in the actual amount of vapor present in the atmosphere, but are always concerned with its degree of saturation, because on this depends the rate of evaporation. The degree of saturation controls directly the difference between the readings of the wet- and dry-bulb thermometers. Tables have been calculated which enable us to read the degree of saturation corresponding to any temperature of the air and difference of readings of the wet and dry bulbs. The degree of saturation is always expressed as the percentage of the total amount of water vapor possible for the air to contain at its given temperature, and it is usually referred to as the relative humidity of the atmosphere, meaning thereby the ratio between the existing amount of moisture in the atmosphere and the total amount which might be contained by it at the given temperature of the dry bulb.

The dew-point.

In this connection it is easy to see what is the significance of the dew-point, as it is called. In the incident referred to above, when a very cold vessel becomes coated with moisture deposited from the atmosphere, the process which takes place is exactly similar to that which takes place during those nights that are characterized by a marked deposit of dew on plants and other dark objects. The air at its prevailing temperature in the one case, or during the day in the second case, is not saturated, but as it cools in contact with the cold objects it is gradually brought to a temperature at which it can



This chart, and others in this book, are redrawn from Bartholomew's "Atlas of Meteorology," London, being Vol. 3 of his Physical Atlas.

of it lie zones that are distinctly poor in precipitation. Two zones of intermediate precipitation over the two tropics.

no longer maintain all its moisture in the form of vapor but must allow some of it to separate as liquid. The temperature at which this previously non-saturated air passes over to a saturated condition marks the dew-point for the atmosphere under those conditions. If the air cools any further, some of its moisture condenses and forms cloud, fog, dew or frost. If the temperature of the dew-point is below freezing, then the moisture, as it condenses, changes immediately to its crystalline solid state, forming what we call frost. Very complete tables for the determination of both dew-point and relative humidity may be found in special works on meteorology and climatology.

Distribution of atmospheric moisture.

The general distribution of atmospheric moisture varies both horizontally and vertically. Horizontally we may expect to find the greatest amount of moisture over the oceans and in their immediate vicinity, while the least moisture would be actually found at the greatest distances from its chief source, and should therefore occur over the interior of the great continental masses. The map of annual rainfall of the world (Fig. 752) shows, as clearly as a rainfall map can do, a decrease in moisture as we proceed from the coasts to the interior of the great land masses. The accompanying table presents the results of computations of temperatures, relative humidity, and the actual amount of moisture in one cubic meter of air, for successive zones of latitude over the whole earth. From this table it appears that the relative humidity is highest near the poles and the equator, while the greatest actual amount of atmospheric moisture occurs within ten degrees of latitude on either side of the equator. The lowest relative humidity in either hemisphere occurs in the vicinity of latitude 30°,

TABLE SHOWING DISTRIBUTION OF ATMOSPHERIC MOISTURE. (Hann.)

Latitude	Mean temp. °C	Relative humidity of year	Grams of moisture in 1 cubic meter of air		
			Year	Dec.–Feb.	June–Aug.
N. 70–60 . . .	-7.0	**82**	3.1	1.2	6.2
60–50 . . .	1.2	78	4.9	2.2	8.8
50–40 . . .	8.7	74	7.0	3.9	10.8
40–30 . . .	15.3	70	9.7	6.5	13.4
30–20 . . .	21.9	71	13.8	10.4	17.1
20–10 . . .	25.4	75	17.2	15.3	19.6
N. 10–Eq. . . .	25.5	79	**18.9**	17.7	**19.9**
Eq. S.–10 . . .	25.1	**81**	18.7	**19.4**	17.9
S. 10–20 . . .	23.2	79	16.4	18.0	14.6
20–30 . . .	19.7	77	13.2	14.8	11.1
30–40 . . .	14.5	79	9.8	11.1	8.1
40–50 . . .	8.7	**81**	7.0	8.3	5.9
S. 50–60 . . .	2.1	(81)	(4.5)	5.7	. .

being lower in the northern hemisphere than in the southern, while the smallest actual moisture contained in the air occurs in latitudes higher than 60 degrees north or south. The table thus shows that there is a steady decrease in the actual amount of moisture in the air from the equator toward the poles at all times of the year, while the relative humidity, which depends on the temperature as well as on the amount of moisture present, is, as might be expected, relatively high about the poles with their low temperatures, as well as over the equator with its prevailing high temperatures. The rainless regions of the earth owe their desert character to various causes, but none of them necessarily indicate the actual absence of atmospheric moisture, and some of them undoubtedly owe their existence to a lack of means for condensing the moisture present.

Fig. 753. Marvin meteorograph.

The amount of moisture contained in the atmosphere decreases as we ascend. Measurements made by means of kites and balloons which have carried up self-recording instruments (see Figs. 753 and 754) have given data for the following tables;

TABLE OF DECREASE IN RELATIVE HUMIDITY, WITH INCREASE OF ELEVATION. (Hann.)

United States . .	Altitude (feet) . .	1,500′	2,000′	3,000′	4 000′	5,000′	6,000′	7,000′			
	Relative humidity %	65	65	65	64	58	59	57			
Germany . . .	Altitude (meters) .	0	500	1,000	1,500	2,000	2,500	3,000	3,500	4,000	4,500
	Relative humidity %	77	71	70	62	57	58	55	49	53	54

but the values here presented have not only strictly local significance geographically, but also are really only characteristic for the weather conditions under which the ascents were made. However, making allowances for these features, they still show very distinctly that the relative humidity of the atmosphere decreases upward. They also show the larger percentage of moisture contained by the strata of the atmosphere near the earth's surface. Consequently, weather conditions that tend to bring down air from higher to lower levels are favorable to the production of dry atmospheric conditions at the earth's surface.

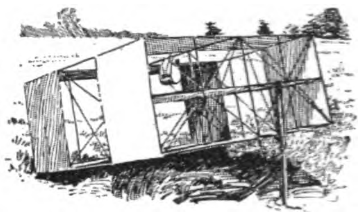


Fig. 754. Kite with meteorograph.

When a mass of partially saturated air is compelled to rise from the surface of the earth and is thereby enabled to expand, the warmth required to produce the resulting expansion in volume draws on the store of heat in the mass of air so that its temperature is reduced in a degree corresponding to its expansion. If the original relative humidity of this mass of air was high, the decreasing temperature that accompanies its ascent will soon reach the dew-point, and then, falling below it, cause some of the moisture to condense in the form of fine drops of water, forming what we call clouds when the mass of visible moisture is floating above our heads. If the initial relative humidity of the air is low, the mass will have to attain a considerable elevation before the temperature will drop to the dew-point, so that the clouds may be formed at very great elevations when the temperature of the dew-point is perhaps many degrees below freezing, and the resulting clouds will then consist of fine ice-needles rather than drops of water; and it is almost certain that the highest clouds do consist of very fine ice-needles. If the current of warm and very moist air moves over an area of cold ground, water or ice, the resulting fall in temperature of the moisture-laden air causes a part of its vapor to condense and form what we call fog, really the same as a cloud except that it rests on the surface of the earth instead of floating a slight distance above our heads. The frequent fogs that characterize various parts of the north Atlantic ocean and the northern coast of the Pacific ocean are the result of this process.

Dew.

In some regions the rainfall is not the only source of the moisture that feeds the vegetation, but the nights are accompanied by very heavy dew; the lighter dew-falls, so called, are characteristic of most regions. The formation of dew has already been briefly referred to, but it may be here further explained. The relative humidity of the atmosphere is maintained at a low stage during the day by reason of the high temperature of the air; but approaching and after sunset the temperature of the air decreases because the steady radiation of heat from all the objects on the earth's surface is then exceeding the amount of heat conveyed to them from the sun, and the air in contact with the earth's surface begins to give up some of its heat to the cooler rocks and soil and plants. Now it is well known that dark objects lose their heat by radiation more rapidly than bright objects, so that the green leaves of the vegetable world rapidly give off the heat that they have received during the day and cool the air in contact with them until it is reduced to a temperature at which it becomes saturated with the moisture that it contains. Then, further radiation by these objects serves to condense the atmospheric moisture on them, that is, cools the air below its dew-point, thus causing some of the atmospheric moisture to collect on the surfaces in round beads and drops, the amount of the same depending on the actual amount of moisture in the air and the temperature to which the objects cool by radiation during the night. When there is a large amount of moisture present in the air during the day, as is the case within the tropics, the nocturnal cooling results in the formation of a large amount of dew, so that a considerable quantity of moisture may be condensed and, by dripping from the leaves, be returned to the earth in this form.

Frost.

The allied phenomenon of frost differs from the formation of dew only in degree. In case of frost the dew-point is not reached until the temperature has sunk below freezing. The injury to plants resulting from frost seems to be of an internal rather than an external character, perhaps resulting more from the freezing of the liquids in the cells of the plant than from the formation of frost on their external surfaces. In either case, the condition to be guarded against is evidently the same, namely, the plant being exposed to a temperature below freezing during the night. From what has been said in the last paragraph, it appears that the low temperatures of either the dew-point or of frost result primarily from the loss of heat by radiation from the objects on the earth's surface, so that if it is possible to prevent a large amount of radiation during a night otherwise favorable for the formation of frost, we should escape the destructive effects of the same. Various methods have been tried to prevent this excessive radiation. The familiar one of covering garden plants with newspapers depends for its usefulness on the fact that the paper is a very poor conductor of heat, so that the heat radiated by the objects covered by it is retained in the air surrounding them, and thus prevents the air falling to such low temperatures. Other methods for protecting large areas, such as the building of smoke smudges, or covering of the beds with awnings made of slats, all make use of the same general principle, which is to stretch a covering of some non-conducting material over the plants close to the ground, thus preventing the loss of heat by radiation that is necessary for the production of frost. [See page 540.]

Forms of precipitation.

The moisture of the atmosphere, which is always present in its invisible form as water vapor, becomes visible in several different forms, taking on either a liquid state, when it occurs as rain, fog and dew, or a solid form when it is generally known as snow, hail or sleet. The differences between these forms are physical. When the moisture is collected into drops large enough to fall rapidly of their own weight, we have "rain." In a more finely divided state the same condition is called fog or cloud, depending on whether the mass of finely divided water rests on the surface of the earth or floats some distance above it. Snow is not merely frozen moisture, but is essentially solid water in a distinctly crystalline condition. A snowflake is an aggregation of ice crystals, usually of beautifully twinned six-pointed, starlike shapes; hailstones also show a crystalline structure, but very often show internal zones of less perfectly crystallized material alternating with highly crystalline ice. Most hailstones have a rounded external shape and betray their partially crystalline character only on being broken open, when it is often found that their core consists of a partially consolidated snow-like mass surrounded by external alternate zones of clear and opaque structure. Occasionally hailstones have been found whose external forms were characterized by hexagonal prism or pyramid faces, thus indicating their crystalline character. The zonal structure of most hailstones has suggested that they owe their origin to repeated partial meltings and refreezings of large aggregations of snow crystals; and the usual association of hailstones with thunder-storms permits us further to explain their formation by supposing them to have been carried from lower to higher levels, and vice versa, several times by the turbulent vertical air currents that accompany such storms. Sleet differs from hail primarily in its size, being much smaller in diameter, and also in its mode of formation, since it seems to result from the rapid freezing of very small rain drops as they descend into the strata of freezing air lying next to the earth's surface. The formation of dew has been explained in the preceding paragraphs, together with its close relative, frost. It is probable that not all the dew that occurs as such represents atmospheric moisture, but may result in part from condensation of moisture exhaled from the leaves of plants or from moist ground. The proportion of dew that is to be ascribed to such sources is not yet definitely determined. The same may be said of frost, except that it seems certain that when frost forms below the very uppermost layer of soil, it is the result of the freezing of the moisture rising by capillary attraction through the lower-lying soil.

Causes of precipitation.

The forms of precipitation in which we are most interested are rain, snow and fog, and the causes which lead to their formation are of prime importance to an understanding of the different characteristics of weather and climate. In discussing the various classes of storms on earlier pages, attention was drawn to the evidences of vertical movements in the air within the centers of disturbance. This movement was particularly easy of identification in the formation of great clouds in the lower atmospheric levels, known as cumulus clouds, which are characteristic of nearly all summer storms. Recalling what has been said about the variations in temperature and pressure with vertical elevation, it is a simple step to the conclusion that if a mass of warm, moderately moist air, as is most of the air near the surface of the earth in the summer months, should for any reason ascend into higher strata, its own temperature would fall as the result of loss of heat by radiation to the surrounding colder layers, and more particularly of the result of its own expansion, due to the decreased atmospheric pressure to which it is subjected. Consequently the original mass of warm moderately moist air may be expected to soon reach a level at which its temperature would fall below its own dew-point, and consequently some of the moisture that it contains will be condensed in the form of fog, or cloud as it appears to us. Observations of summer storms or summer cloud-building generally show that this condensation of moisture from ascending currents of warm air is going on steadily; and a moderately careful observer will have noticed that the many different vertical currents begin to lose their moisture and to form clouds at about the same elevations. It is not necessary, however, to confine our consideration to summer conditions, for, as has already been pointed out, within areas of cyclonic disturbance, that is, areas of low pressure, we have also found evidences of vertical movement, complicated, to be sure, with a rotary motion. And here, also, clouds form rapidly overhead, amid the whirling ascending mass of air, when the supply from below was derived from regions of characteristically warm, moist atmosphere. If we compare the sky conditions over the centers of low pressure with conditions over centers of high pressure, we find a striking contrast between the two, as has already been pointed out. Centers of high pressure are always characterized by absolutely small percentage of clouds, while the cyclonic centers are centers of cloud-making. The study of the wind movements about the two centers shows that the centers of high pressure are also characterized by a general downward tendency of the air over them (see Figs. 747 and 748), while the centers of low pressure are characterized by upward currents (see Figs. 744 to 746), so that here also it seems to be a significant fact that clouds are forming in regions of ascending currents, but not in regions of descending currents. Referring to Fig. 749, which illustrates the relations between wind direction and mountain ranges in the case of the Chinook wind, or Foehn, we find that the windward side of the mountain is represented as being completely covered with clouds whose bases are giving off a heavy rainfall, while the leeward side of the mountain is covered with cloud only on the very highest slopes, and is completely free from clouds at a very short distance from the crest of the divide. In this case the horizontal movement of the wind is evidently deflected into a more nearly vertical one by the obstructing mountain range, and here again we find that, when the air is forced to move upward into higher levels of lower pressure, it is compelled to decrease in temperature, and consequently to give up a considerable part of its moisture content in the form of rain or cloud, or both. These facts make it clear that atmospheric moisture may be condensed into cloud and rain as the result of vertical currents in the atmosphere, and these vertical currents may result either from great cyclonic disturbances such as accompany the storms of the temperate latitudes, or from the convectional currents that spring up at many points over a heated land or ocean, under otherwise quiet conditions of the atmosphere, such as characterize summer weather or predominate within the limits of the torrid zone. On the other hand, we do not expect to find rain and clouds forming in considerable amounts under any conditions where the air is being forced to descend from higher to lower levels. The thunder-storms that are especially characteristic of mountain ranges in summer are probably due also in large part to this general tendency of ascending currents to form clouds and rain, since mountain ranges are especially subject to vertical convectional currents during the day, as the result of the strong difference in temperature over short distances.

Rain may be formed also as the result of winds blowing from a relatively warm and moisture-yielding ocean surface over cold continental land surfaces in the winter. Such a direction of wind would probably result only under the compelling influence of a cyclonic disturbance, since the normal direction of the movement of the air during the winter is from the center of the continents toward the oceans.

Methods of measuring rainfall.

In order to compare accurately the amount of moisture precipitated from the atmosphere of different regions, or of the same place at different times of the year, it is necessary that we have some accurate means of catching and measuring the rain that falls on the earth's surface. The instruments used for this purpose are known as rain-gages, and the standard rain-gage used by the United States Weather Bureau is shown in Fig. 755. This consists essentially of a sharp-rimmed circular brass funnel which catches the rain that falls over a definite area, namely, that of the large opening of the funnel. The funnel conducts the water into a narrow cylinder of brass inclosed within a larger one of galvanized iron. In Fig. 755, the cylinder with the measuring stick in it is shown standing to the right of and outside the gage and its support. The diameter of the narrow brass cylinder bears a definite relation to the diameter of the mouth of the funnel, the construction being such that one inch of water in the narrow cylinder corresponds to one-tenth of an inch of rain falling over an area equal to that of the mouth of the funnel. It is necessary that the funnel rim should be very sharp in order that there may be no splashing of drops as they strike it. The object of the larger galvanized iron cylinder that contains the small brass cylinder is to catch any additional rain that falls after the brass cylinder has been filled to overflowing; this galvanized iron cylinder is therefore called an overflow attachment, and provides a means for preserving the additional fall of rain, so that it may be measured and added to the amount which the brass cylinder holds when brimful. The rainfall is measured by inserting a properly graduated flat measuring-stick of red cedar into the brass cylinder, and reading off on the measuring stick the height to which the water in the cylinder reaches. The measuring-stick is so graduated and marked as to give, by direct reading, the depth of water which falls over the area of the large opening of the funnel. In the winter the brass cylinder and funnel should be removed if snow is expected, the large overflow cylinder of galvanized iron being left exposed to serve as a snow-gage. In getting records of snowfall it is highly important for many purposes that both the average depth of snow and the equivalent of this snowfall melted to water should be recorded. This can best be accomplished by cutting out with the galvanized cylinder a block of snow on a level where the average depth may be obtained, and carefully melting the cylinder of snow, after which the resulting water may be poured into the narrow brass cylinder and measured just as if it were so much rain.

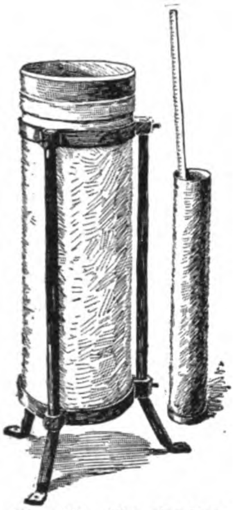


Fig. 755. The standard rain-gage used by the United States Weather Bureau. The cylinder into which the rain passes is shown at the right, with the measuring-stick projecting. The gage and its support on the left.

Such a gage requires a great deal of attention on the part of the observer, as it does not automatically record the amount of water which falls as rain. In order to secure continuous records of rainfall during heavy or long-continued storms, when perhaps it would be inconvenient to make observations by hand, a form of automatically recording rain-gage has been invented by the United States Weather Service, in which the funnel conducts the rainfall into a double-ended bucket delicately balanced, so that as soon as one end is filled it tips down and brings the empty end into position, at the same time discharging its own load. Thus the ends of the bucket are alternately filling and discharging, and as the contents of each end are accurately known, the number of times the bucket rocks back and forth, if carefully recorded electrically, gives an indication of the amount of rain that falls in any given length of time. This is known as the tipping-bucket gage and is represented in Fig. 756.

Although it is very important that the parts of the gage be accurately made, and especially that the outline of the brass rim of the funnel remain accurate and true, yet by far the most important factor for securing accurate measurements of rainfall is the manner in which the rain-gage is exposed to the storm. The eddies set up about the mouth of the gage by high winds produce very serious fluctuations in the amount of rain that falls within the area of the funnel and may frequently cause the gage to record quite inaccurate results. In order to overcome this very important source of error various improvements have been proposed, the most practical one being that which proposed to provide the mouth of the gage with a peculiar flaring collar or shield, whose curve is so calculated as to break up these eddies. Much the same end is attained if the gage be located at the center of an extensive depressed roof, so that the walls of the building act as shields to break the force of the wind and thus produce practically calm conditions about the mouth of the gage. It is also of great importance that the gage be so located that it stands free of any possible eddies that may be produced by objects in its vicinity, such as houses, outbuildings, trees and bushes. Ordinarily the ideal location of the rain-gage would be in the center of a broad open space surrounded with trees at a distance from the gage not less than the average height of the trees, with the funnel opening standing two or three feet above the ground.

Variations in rainfall.

The chief cause of variations in the amount of rainfall from place to place over the earth's surface is naturally sought in differences in elevation between places, as has already been seen in the section dealing with the causes of rainfall (page 589). Attention was also drawn in that section to the fact that certain levels in the atmosphere seemed to be characterized by a larger number of clouds than others. The zone of most frequent clouds lies between a mile and half a mile above the earth's surface, since currents of ascending air usually reach the dew-point at about this elevation and the clouds attain the greatest density at about the same elevation, because the condensation from ascending currents which takes place at higher altitudes yields smaller amounts of visible moisture, owing to the smaller amount of moisture which the air is able to hold in suspension at

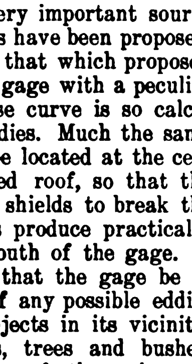


Fig. 756. Tipping-bucket self-recording rain-gage.

the lower temperatures. For the same reason the greatest rainfall occurs not at the earth's surface but at some short distance above it, depending on the region and the season. Some of the moisture that is condensed and combines at the lower limits of the clouds to form rain is lost by evaporation before the whole quantity is able to reach the earth's surface. Indeed, in regions where the earth is very dry, rain may fall from clouds above it, but completely evaporate before it reaches the earth's surface. The altitude of the zone of maximum rainfall occurs in the Alps at an elevation of between 3,000 and 4,000 feet in winter, but in summer seems to lie some distance above the crests of the mountains. The accompanying table shows the variation in rainfall with the regular increase in height in certain districts of Europe:

I

RAINFALL IN JAVA.

	Batavia	Meester Cornelis	Pasar Mingo	Depok	Bodjong Gedeh	Buitenzorg
Distance from the coast (km.)	7	11	17	33	43	58
Altitude (m.)	7	14	35	92	130	265
Rainfall (cm.)	180	180	244	306	373	443

RAINFALL OF MITTELGEBIRGE, GERMANY.

Altitude (m.)	100–200	200–300	300–400	400–500	500–700	700 1,000
Rainfall (cm.)	58	65	70	78	85	100

RAINFALL IN THE BARBADOES.

Altitude (m.)	50	140	240	over 280
Rainfall (cm.)	111	121	142	158

RAINFALL IN THE PYRENEES.

Station	Tarbes	Bagnères	Station Plantade	Pic du Midi
Altitude (m.)	308	555	2,366	2,860
Rainfall, winter (cm.)	36	64	99	97
Rainfall, summer (cm.)	46	65	114	64
Rainfall, year (cm.)	83	129	213	161

The following table shows the same phenomena for one set of stations in California and Nevada:

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RAINFALL ACROSS THE SIERRA NEVADA, U. S. A.

	Colfax, Calif.	Iowa Hill, Calif.	Emigrant Gap, Calif.	Cisco, Calif.	Summit, Calif.	Truckee, Calif.	Boca, Calif.	Reno, Nev.
Altitude (feet)	242	3,825	5,230	5,939	7,017	5,818	5,535	4,484
Annual precipitation (inches)	46.6	52.2	52.4	49.6	46.5	27.0	20.0	5.4

This increase in rainfall with increased elevation is particularly well brought out in the rainfall maps of those countries where the rainfall has been recorded at a number of stations well distributed over highlands and lowlands. Such maps are available for a number of European countries, but we have not the data to construct one for the United States. In the former case the rainfall maps show a striking resemblance to and coincidence with the hypsometric maps of their respective regions.

The rainfall generally decreases in amount as we proceed inland from the coastal regions of the continents, since it is from the oceans that most of the moisture is derived, while the interiors of the continents not only lie at maximum distances from the most plentiful source of moisture, but tend to maintain the highest temperature during the summer months. In large part, also, the distribution of rainfall is influenced by the distribution of plains, plateaus and mountain ranges. The plains offer small opportunity for compelling the moisture-laden air to rise into levels at which the moisture must be condensed into the form of rain or cloud, and furthermore they may lie in the interior of the continent so far below the zone of maximum rainfall, as has already been suggested, that the rain which falls from the clouds above them never reaches the surface. On the other hand, the mountain ranges and plateaus are generally better supplied with rainfall, since they either compel the air to rise and thus initiate condensation on their slopes, or, as is the case with some of the interior plateaus, reach up to levels sufficiently high to catch the rain from the clouds floating above them before it has all evaporated during its passage downward through the warm atmosphere. In many cases, however, the two sides of a mountain range present strong contrasts in rainfall, depending on the direction of the prevailing winds, notable instances of this being the South American Andes, North American Sierra Nevadas and the Himalayas of northern India.

Distribution of rainfall.

We have considered various causes which produce variations in rainfall, and have found that there is a decided variation vertically, as well as more or less irregular variations from place to place, depending generally on the altitude and the distance from the oceans or other large bodies of water. If we turn now to Fig. 752, which presents the general distribution of rainfall over the surface of the earth as a whole, we notice that the equatorial zone is the region of generally heaviest rainfall, while to the north and south lie zones that are distinctly poor in precipitation. Two zones of intermediate amount of rainfall have their axes over the two tropics. Comparing this general distribution of rainfall with the maps of winds of the world (Figs. 735 and 736), it is at once evident that these zones of rainfall agree more or less closely with the broad belts of the terrestrial winds and calms. The zone of maximum rainfall is found to coincide in a general way with the zone characterized by weak, uncertain winds called the doldrums, while along the two tropics occur the zones of generally least rainfall coinciding with the regions of the trade-winds. Finally, the zones of moderate rainfall which characterize the temperate latitudes of both hemispheres correspond with the regions dominated by prevailing westerly winds with their extra-tropical cyclonic storms. This general association of rainfall distribution with the belts of terrestrial winds thus agrees with what we would expect from our knowledge of the chief causes of rainfall.

The relatively cloudy conditions of the atmosphere within the doldrum belt are, as we have already seen, very favorable to the production of vertical, convectional currents, and these conditions indeed give rise to the familiar weather of the equatorial regions, which is characterized by frequent daily thunder-storms of considerable violence, accompanied by very heavy downpours of rain. On the other hand, the bordering trade-wind regions are under the influence of strong constant currents of air which are descending from higher and drier atmospheric levels, and are therefore rapidly warming and taking up moisture from the surface of the oceans and the lands over which they blow. This statement needs to be modified only for those regions in which the topographical features of the continents compel the trade-winds to ascend, instead of permitting them to continue on a course close to sea-level; when they meet with such interruptions they are of course compelled to give up a certain part of their moisture. This is beautifully illustrated in the case of northern South America, where the steady rise of the southeast trades, compelled to rise gradually from the Atlantic coast to the summit of the Andes, is very perfectly reflected in the rainfall map of South America shown on a small scale in Fig. 752, where it appears that the rainfall increases steadily from the mouth of the Amazon to the Continental Divide. The same feature is shown in the distribution of rainfall on the island of Borneo and over the Philippine archipelago, in both cases the heaviest rainfall being on the slopes of the mountains toward their respective trade-winds. The dry character of the trade-winds when near sea-level, and their constant tendency to absorb moisture from ocean and land, is well shown by their effect on northern Africa. Here exists one of the largest deserts of the world, the Sahara, which clearly owes its existence to the desiccating effects of these winds and to the absence of any considerable mountain ranges in that section of the continent. Deserts of this kind may be designated by the general term of trade-wind deserts. In the region of the horse latitudes we find the weather prevailingly fine and the skies clear, the air fresh and moderately cool. All these features indicate that the air in these regions is descending and warming and drying under increasing pressure. It is not to be expected that the horse latitudes will be characterized by considerable rainfall. The necessary convectional currents are not readily developed under the conditions of pressure and general atmospheric circulation which prevail there. Passing to the regions controlled by the prevailing westerly winds, we find the physical conditions somewhat different in the two hemispheres. The greatest expanse of land in the northern hemisphere lies under the latitudes of these winds, while in the southern hemisphere the rapidly narrowing southern extremity of South America is the only considerable land mass within their sweep. What information we have concerning the weather conditions and rainfall of the Antarctic ocean leads us to believe that the prevailing westerlies of the southern hemisphere maintain a repeated succession of cyclonic disturbances which are accompanied by somewhat heavier rainfalls than those of the northern hemisphere, and by stormy winds with almost constant cloud and fog. The control of rainfall by topography is again well illustrated in that section of South America that extends into the region of prevailing westerlies. The heavy rainfall of this region results from the interruption of the prevailing westerlies by the high mountain ranges of this coast, just as the heavy rainfall of equatorial South America lies on the eastern slopes of the same range, that is, on the slope toward the southeast trades.

In the northern hemisphere, the region of the prevailing westerlies owes most of its rainfall to the disturbances produced by the cyclonic storms of those latitudes. These storms traverse both North America and Eurasia from west to east.

Their fronts, as we know, are formed by the currents of warm, moist winds from the southeast and south, consequently we expect to find them giving up most of their moisture along the western boundaries of the continents and bringing the smallest amounts of rain to the interiors of the same, since the storms are there at the greatest distance from the source of supply. It is therefore not surprising to find that the central parts of North America and of Asia are among the driest regions of the world. The same reason holds good in part for the continental mass of Australia.

The eastern coasts of both North America and Asia enjoy moderately heavy rainfalls, as is shown in Fig. 752. This is due in large part to the increased amount of moisture which the cyclonic storms are able to bring in from oceans lying to the east and south. In this connection it is worth while to draw attention to the relative positions of the Gulf of Mexico and the Sahara Desert of North Africa. The Gulf of Mexico furnishes a large amount of moisture to the trade-winds blowing over it toward the Isthmian part of North America, and also to the warm southeast and southerly winds blowing northward into the storm-centers of the winter. Thus the southeastern and eastern states of North America have a much heavier rainfall, in spite of their relatively low altitude, than would be possible if a land mass occupied the position of the Gulf. In comparing the rainfall maps of Asia and North America, it is also interesting to note that the driest region of North America does not occupy the central position with reference to the continent as does the corresponding region of Asia, but that it lies west of the center. In connection with this we must note the very heavy rainfall that characterizes the Pacific coast of North America. A portion of the moisture that the prevailing westerlies secure from the North Pacific is combed out as soon as they begin to ascend the Coast Range and the Sierra Nevada. The elevations to which the storms and prevailing westerly winds are thus compelled to attain soon after reaching the western coast of North America, and the attendant loss of part of their moisture as rain, convert them into rapidly drying winds when they are compelled to descend the eastern slope of the Sierras and cross the great interior basin of the continent. In consequence of this the prevailing conditions over the interior basin are those of dry air and clear skies, imposing almost complete desert conditions on the ground beneath them. Similar conditions seem to characterize the eastern slope of the extreme southern Andes and the northern slopes of the Himalayas, although in the latter case the winds which are desiccated by the lofty mountain ranges are not the stormy winds of the prevailing westerlies but usually the southwest monsoon of the Indian ocean. Thus the great interior desert of North America seems to be a typical example of a desert due to the surface features of the continent and is not to be confused with trade-wind deserts such as the Sahara.

The precipitation of the polar regions is characteristically small, a fact that we are already prepared for by the table on page 588. The total annual fall is generally below ten inches, except where considerable mountain ranges interfere with the prevailing winds. Although the actual amount of moisture present in the atmosphere is here at its minimum, the low temperatures give a high relative humidity which would be favorable to more frequent precipitation if ascending air currents were general.

The seasonal shifting of the temperature belts and of the terrestrial wind system involves a cotemporaneous shifting of the belt of equatorial rains, since this must move north and south with the doldrums (see Figs. 732 and 733). The consequences of this are that some stations within the tropics experience two rainy seasons and two relatively drier seasons, according as the sun is overhead or to the north or south of them. Another consequence of this seasonal shifting of the wind belts is that those regions which lie along the equatorial side of the two trade-wind belts are subject to regular alternations of rain and fine weather corresponding to the seasonal shifting of the doldrum rain belt. A striking example of this alternation of wet and dry seasons is furnished by the region about the head of the Nile. When the sun is south of the equator the head-waters of the Nile have their dry seasons and therefore reach their lowest stages; but when the sun has reached its northernmost position, the Nile source lies within the western boundaries of the southwestern monsoon of the Indian ocean and receives the heavy precipitation which causes its summer floods.

The same seasonal changes appear even more strikingly in the monsoon region of India. During the northern winter the northeast trades combine with the winter monsoon, which blows from the mountains over the northern Indian ocean, and thus nearly the whole of India has its dry season. During the summer months, on the contrary, the very high temperatures of interior Asia have brought the low pressure of the doldrums to unite with that of India and Persia, so that the southeast trades crossing the equator are converted into the southwest monsoon and, heavily loaded with moisture, drive against the steep slopes of the Deccan and the lofty Himalayas, producing over these regions one of the heaviest rainfalls known on our globe. This rainfall amounts to 40 feet in a year over the southern slopes of the Himalayas north of the Bay of Bengal, and nearly all of this flood falls during the months from May to September. While the heavy rainfall in the doldrums shifts back and forth within the approximate limits of the tropics, the belts occupied by the trade-winds suffer corresponding shiftings. Those regions that lie close to the poleward boundaries of these trade-wind belts show a corresponding marked contrast between the rainfall during the prevalence over that region of the prevailing westerlies and the small rainfall that characterizes them during the prevalence of the trade-winds. The belts in which the rainfall shows this seasonal variation are called the regions of subtropical rains.

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