A FAMILIAR SIGHT: Flooding, such as this inundation north of Seoul, South Korea, in 1998, may become more common with global warming.

WARMING TO CLIMATE CHANGE

Global warming is upon us, scientists say—and some communities are ready to react. Together researchers and local leaders are planning for hot, wet—or just plain bizarre—weather to come

by KATHRYN S. BROWN

For geophysicist Gunter Weller, getting to the office is a real trip. On weekday mornings around 7 A.M., Weller gingerly backs his black Toyota SUV down the driveway and into the icy fog that shrouds Fairbanks. His car creeps, antlike, for three miles to the University of Alaska. It's not the morning darkness—or even the icy air—that puts Weller on guard. Rather it's the sudden lurches and gaping cracks that emerge from nowhere in the road—scars of the permafrost melting below the ground.

Record warm temperatures are gnawing away at the masses of ice that lie beneath Alaska and other Arctic areas—and, in the process, buckling roads, tilting trees and threatening homes. Eventually much of the boreal forests that color Alaska could dissolve into wetlands, which could, in turn, become grassland. This ecosystem makeover is a dramatic show of climate change—and perhaps a distressing harbinger of things to come. "We are beginning to see the greenhouse effect—and it's not pretty," notes Weller, director of the university's Cooperative Institute for Arctic Research.

Most scientists now agree that global warming is quite real. The past decade has been the Northern Hemisphere's warmest in 1,000 years, and solar variability and other natural phenomena cannot alone explain the temperature patterns, researchers say. At the same time, freaky weather events—from permafrost thaw in the Arctic to El Niño–driven drought in Indonesia—are putting climate on the radar screen in a new way. Last fall North Carolina residents endured three hurricanes in two months. "After that, we have newfound respect for storms, and we're more open to looking at the possibilities of global warming," remarks Barbara Blonder, a site manager of North Carolina's Division of Coastal Management.

Forecasting regional climate changes—the future temperatures, storms or landscape shifts in the midwestern U.S., say, or along the Australian coast—isn't easy. Climate models are coarse, and zooming

YONHAP AP Photo

in on any given region does not provide an accurate picture. Still, many scientists would like to help communities brace for—and in some cases even benefit from—global warming. So they are teaming up with local leaders—including farmers, forestry managers and government officials—to sidestep the gaps in climate models and encourage resourceful strategies for protecting communities. "Uncertainty about climate change isn't going to be erased for a long time," remarks Richard H. Moss, a climate scientist based at the Pacific Northwest National Laboratory in Washington, D.C. "Even so, there are ways to manage the risk that you face."

STEVEN SPRAGUE *Panos Pictures*

ARBOREAL SEAWALL: Vietnam has cultivated mangrove trees for firewood and honey—but scientists say these plantings yield an indirect benefit of holding back rising seas.

Preparing Now

Management strategies range from simply getting out of nature's way—moving people out of a floodplain, for example—to building up wetlands, investing in diverse crops and rethinking water markets. The best solutions depend on a community's unique resources, economy and concerns—things scientists can pin down only by leaving the lab and talking to people. The largest such effort is the U.S. Global Change Research Program's National Assessment, in which a team of scientists from various disciplines fan out across the country, holding town hall–like meetings and writing reports on climate's potential impact in various states. "We're trying to find out how climate affects people, listening to their questions, thinking of solutions," remarks Michael MacCracken, head of the assessment's coordination office.

In the Mid-Atlantic region, Pennsylvania State University agricultural economist Ann N. P. Fisher has found that area residents are worried about global warming's effect on the coastline. Will more raging storms flood nearby farms and carry runoff into drinking water? What about the opposite problem, drought? "Win-win" strategies can be deployed that make sense on either front, Fisher says—more tightly regulating farm waste, for example, and conserving water. One solution might be metering city water in Pennsylvania, so that residents pay for the amount of water they use and are thus encouraged to use less.

Indeed, conserving natural resources, whether water or land, often emerges as a way to grapple with climate change. Climate models predict that higher temperatures will turn white winters into wet ones in the western U.S., with more precipitation coming down as rain than snow. Warmer temperatures may also hasten the melting of snow crowning the Rocky Mountains, causing winter floods and leaving less of the spring/summer snow melt normally used for drinking water and crop irrigation across much of the West. To adapt to any impending change, water managers may need to rethink the way they operate existing reservoirs to capture more winter flood flow, whereas farmers might favor drought-tolerant crops or more efficient irrigation techniques, comments Peter Gleick, director of the Pacific Institute for Studies in Development, Environment and Security in Oakland, Calif. "We don't necessarily need new tools to cope with climate change—we just need to be better at figuring out where and when to apply the tools we have," Gleick adds.

In some cases, old tools may come back into vogue. Before Europeans established farms across the U.S., Native Americans had their own ways of growing crops in a harsh climate. One strategy was pebble mulching—layering gravel over crop fields to soak up scarce rainfall. Some Pueblo Indians can still recall pebble-mulched farms along the Rio Grande. A similar style is the grid garden, a rectangular slice of field covered with cobblestones that collect water. "It's not designed to feed Phoenix," concedes anthropologist Richard P. Watson of San Juan College in Farmington, N.M. But Watson observes that such techniques could sustain small communities—particularly Native Americans living on federal reservations, who would find it difficult to simply move to more fertile ground.

As is true of water, conserving land from development can sometimes protect a community, a lesson that North Carolina residents learned the hard way. Last fall hurricane-whipped floods soaked hog and poultry farms in the state's floodplains, bloating animal waste lagoons and threatening private wells with water awash in feces and urine. Landfills, trash dumps and wastewater treatment plants, too, all went under, littering the floodwaters with their contents, says Larry Ausley, a water quality supervisor for the state. "Above all, we've learned that we really don't own these floodplains; we just borrowed them for a while," Ausley notes. In the aftermath of Hurricane Floyd, North Carolina's Department of Environment and Natural Resources announced that farmers would not be allowed to rebuild waste lagoons that were severely damaged in the

LIFE IN A HOTTER WORLD

Nothing screams "New England" like the sugar maple—a showy, sappy tree crowned with fiery orange leaves every fall. This autumn flush is New Hampshire's very personality. But the hand of global warming may dull the region's orange luster—mixing in more subdued yellow, as aspen trees take over the landscape. In much the same way, climate could redecorate backyards worldwide, shifting the scenery like a painting in progress—and dabbing away at our very sense of place.

This is the personal side of climate change—and it worries researchers almost as much as do the logistics of planning for higher seas or less rainfall. "We know the world can ultimately deal with climate practicalities, like changing crops in the face of drought," says agricultural economist Richard M. Adams of Oregon State University. "But how will global warming change the color or culture of a region? Maybe you won't see all the dairy cows on the hills in Switzerland, or maybe you'll find the wine market moving from northern California into Canada. The question is, How will these changes in regional identity play out?"

Climate change isn't new, of course—the earth is forever evolving, and ecosystems naturally surge and fade over time. But scientists suggest that global warming is speeding up the process. And in a mere 50 years, they say, familiar landscapes could take on a whole new look. The so-called prairie peninsula—a blanket of yellow grasses softening the horizon in the Midwest—could fill up with trees as increasing rainfall stifles the periodic fires that normally clip prairies. Further south—across Arizona, Texas and into Mexico—summer rains have already begun littering grasslands with squatty mesquite. And in a future New England, "people may be nostalgic for those beautiful falls," predicts ecologist Steven P. Hamburg of Brown University.

KARL NEUMANN *Index Stock Imagery*

SUBDUED YELLOWS: A warmer climate may encourage the growth of more aspens and fewer maples in New England, blunting the colors of fall there.

These shifting landscapes pay no heed to our sense of boundaries, such as those marking the edges of national parks. Across Canada, more than two dozen parks protect caribou, whooping cranes and other endangered species—not to mention treasured habitat, such as rain forest and prairie grass. But warmer temperatures may lure both animals and plants north, outside a park's protective borders. "The park can't just up and move," remarks Roger Street of the Atmospheric Environment Service in Ontario. And no one knows how park inhabitants—from birds to bears—will fare in the real world, outside the shelter of their existing homes. Some species probably will disappear entirely, while others hopscotch north in unpredictable patterns.

Ironically, in Europe, global warming could mean a decades-long cold snap—thanks to changes in the North Atlantic Ocean. Normally, salty, dense water on the North Atlantic's surface sinks predictably, creating a current of warm air that wafts toward Europe. But as the globe warms, increasing rainfall in high latitudes will lead to less salty water in the North Atlantic, disrupting the ocean's normal circulation patterns—and cooling the air currents above. Some researchers even suggest that London will become more like Copenhagen, with winters that average at least 10 degrees Fahrenheit cooler than they do now.

In most places, though, climate change will merely blur the borders of regional identity, scientists say. The U.S. corn belt won't suddenly relocate to Canada—but it could creep 50 to 100 miles north, into Michigan and Minnesota. And at the southern end this farm belt could become more sorghum than corn, because sorghum tolerates heat well. "Few people will stand up and yell, 'Aha! The climate has changed!'" Hamburg says. "But we may well notice that our world looks oddly different than it used to." — *K.S.B.*

floodplain. Many coastal managers argue that flood insurance also should be abandoned, because it encourages people to put their houses right back in harm's way.

The North Carolina disaster also shows how important wetlands can be: they give rivers and oceans room to swell harmlessly. In the Chesapeake Bay, rising sea level—one of global warming's more discernible effects—will swallow today's wetlands, says Donald F. Boesch, president of the University of Maryland's Center for Environmental Science. "That's something we can plan for," Boesch comments. He tells water managers that the time to build up intertidal wetlands in the Chesapeake is now. Similarly, British scientists are lobbying to place mangrove forest barriers on Vietnam's coast, and Australian researchers are warning coastal governments in Queensland to factor more intense tropical cyclones into flood management programs.

Saving water and setting aside land are safe bets for dealing with climate change. A greater challenge, perhaps, is rolling with nature's punches—heat waves, dry spells and other weather patterns that turn an ordinary season into a roller coaster of extremes. And such schizo-

Heat waves, dry spells and other schizophrenic weather patterns that turn an ordinary season into a roller coaster of extremes could increase in frequency with global warming.

phrenic weather patterns could increase with global warming, because warmer temperatures are likely to disrupt the normal water cycle, causing more frequent violent storms and, paradoxically, more prolonged droughts in some regions. Scientists still cannot forecast climate variability decades down the line, but they are learning how to predict it on a seasonal basis. And agencies like the National Oceanic and Atmospheric Administration are eager to put these climate forecasts to use. To that end, NOAA has sent dozens of scientists to remote communities across the globe.

In Zimbabwe, agronomist Jennifer G. Phillips of the National Aeronautics and Space Administration Goddard Institute for Space Studies and her colleagues have surveyed more than 200 farmers to see how they use climate forecasts to plan such crops as corn, millet and sorghum. Like those elsewhere, Phillips remarks, farmers in Zimbabwe say mercurial weather makes planning for crops difficult—seasons may start dry yet end in floods, thanks to weather events like El Niño. Many African farmers plant up to eight crops, so a reliable dry climate forecast might prompt them to focus on the use of drought-tolerant grains such as millet, sorghum and certain types of hybrid corn, Phillips says: "If farmers know that chances for a bad year are high, they might figure that into their yearly planning—saving back some seed stock, maybe selling more oxen or moving cattle to a neighboring farm that boasts a better pasture or better water."

The southern Africa research has only begun, but investigators have already endured one hard lesson: the impact of an incorrect forecast. Climate scientists predicted relatively dry conditions for much of southern Africa during the 1997–98 rainy season, but radio reports had exaggerated the potential drought. Many farmers planted less land than they would have normally, Phillips points out. These farmers lost out when normal levels of rainfall trickled over their unused land. Forecasts can backfire, Phillips notes: "If we tell farmers to invest in a little fertilizer or plant more rice and we're wrong, we may be exposing them to more risk than if we said nothing at all." Still, she is optimistic that climate forecasts will continue to improve and that farmers can benefit.

Crop Snapshots

NASA, too, has a high-tech take on climate variability. It funds the Upper Midwest Aerospace Consortium at the University of North Dakota, which is offering more than 200 farmers and ranchers in the northern Great Plains weekly satellite images of their fields. These snapshots from space may help guide crop decisions (say, how much fertilizer or fungicide to spread on crops) or ways to plan land use for livestock. As earth systems scientist George A. Seielstad of the University of North Dakota explains, the idea is to see whether farmers and ranchers can use remote images of their land throughout the course of the growing season to maximize crop yields. This kind of flexibility could be critical in the future. "For most of this decade in North Dakota, it has been exceptionally wet," Seielstad says, "and, as a result, fungi are feasting on spring wheat and potato crops. The lesson is that when the weather takes a turn, it affects agriculture in a big way, and people have got to adapt."

What ranchers want most is resiliency—the ability to bounce back from whatever nature lobs their way, according to Robert Ravenscroft, a cattle rancher in Valentine, Neb., and a participant in the National Assessment. One strategy already being implemented is diversification. Ravenscroft maintains his own adult cattle herds and takes in groups of calves from other ranches. He also keeps careful watch over the plants that make up his rangeland, checking for a good mix of grasses that favor cool and warm seasons or a fair blend of plants with root systems that tap into shallow soil or snake further down. "These kinds of diversity give us staying power," Ravenscroft comments.

Resiliency also counts on the urban frontier. Climate shocks to the world's most important cities—such as New York,

J. SCHMID *Tropix*

ADJUSTING TO EXTREMES: Southern African farmers would benefit greatly from more accurate climate forecasts that would allow them to better plan for inevitable droughts, such as this one that struck fields in Zimbabwe in recent years.

Tokyo and London—could shake up economies worldwide. By 2090 increasing storm surges could dunk lower Manhattan under water every few years, flooding the World Trade Center and other financial district skyscrapers and threatening the water supply with salty sludge from the Hudson River, according to Cynthia E. Rosenzweig of Columbia University and the NASA Goddard Institute for Space Studies. New Yorkers might stave off disaster by taking these forecasts into account when renovating buildings or transportation systems. Already, the Port Authority of New York and New Jersey has factored the possibility of future sea-level rise into projects at John F. Kennedy International Airport, boosting the drainage end of a storm sewer system by more than a foot. "With a little planning, we can make the city more robust," contends Rosenzweig, co-chair of the National Assessment's metropolitan East Coast team.

The trick, researchers assert, is to seek out these "no-regrets" strategies—logical ways to manage the environment that will pay off if climate forecasts come true. In the southeastern U.S., timber companies are engineering loblolly pine trees that can endure drought, an especially useful trait, given the sandy soil and dry skies that can leave forests in the area parched. If the area does happen to grow hotter and drier in the future, these trees—and other genetically engineered species yet to come—should adapt better to the new climate conditions.

That's not to say that climate strategies come easy, or even at all, for some people who may be affected. Forestry managers can't use today's climate models to plan 30 years down the line, according to Lloyd C. Irland, a forestry consultant in Winthrop, Me. "Will there be more oak trees farther north?" Irland asks. "How are white pines going to change in their range? Timber is a regional market, and climate models can't tell us precisely how regions are going to change. That makes it hard to plan ahead."

To forecast regional climate changes, scientists try to scale down results from popular global circulation models (GCMs). But sometimes these models do not agree. For the Great Lakes region, the Canadian Climate Model suggests a warmer and drier future than another simulation, the Hadley model, does. The contradiction results in different scenarios for crops or even area lake levels, critical to Michigan's $5-billion recreational boating industry. "We have to fine-tune the models to get a clearer picture of the future," says meteorologist Peter J. Sousounis of the University of Michigan. Until then, he hesitates to give anyone advice for adapting to the coming climate.

In Alaska, residents are getting a crash course in climate change—and adapting isn't simple. Local governments are spending a fortune ripping up roads, digging out the chunks of permafrost—sometimes 15 feet deep—and relaying the pavement. Life is even more challenging on the coast, where native Alaskans live in isolated hunting and fishing villages. These villagers report that melting ice along the coast of the Bering Sea is ever harder to navigate on snowmobiles and that seals, walruses and whales are growing more scarce, reports the University of Alaska's Weller. There are plenty of practical, though expensive, solutions, he notes: relocating villages to higher ground, building sea walls or importing food. But these logistical strategies are of little comfort to native villagers. "We're talking about drastically altering the lifestyle and cultural traditions of these people, and they are reluctant to give it up," Weller says. And for that, he declares, there is no scientific solution.

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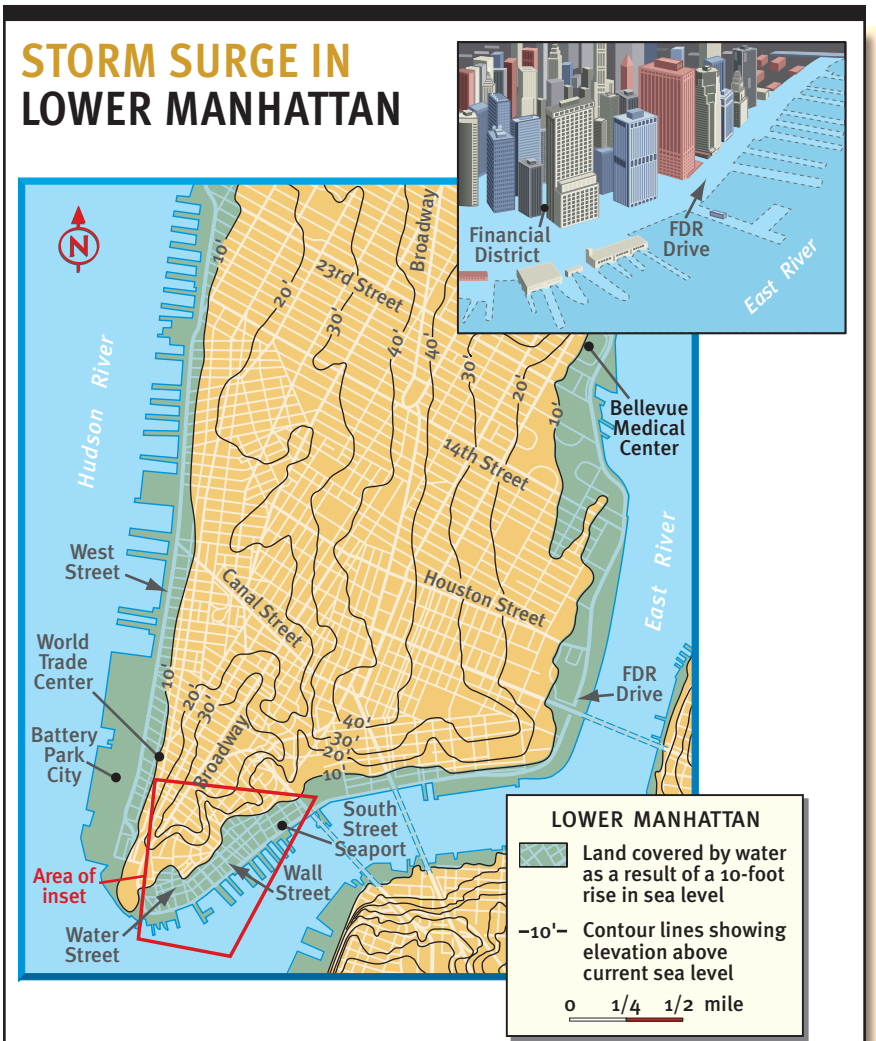
STORM SURGE IN LOWER MANHATTAN



Rising waters could be submerging lower Manhattan periodically by 2090 if global warming proceeds as at least one climate analysis has projected.

MATT KANIA