savanna into desert, and converting woods to farmland or, eventually, into parking lots. The researchers started out with a map of the world's potential vegetation at the dawn of civilization—based on factors like climate and soil type—and simulated a satellite map to compare with actual satellite maps of global vegetation today.

Then, to estimate how much carbon was released as lands were altered, the duo and their collaborators plugged the before-and-after satellite maps into a computer model that converted the greenness of each area into how much carbon was stored in that landscape, be it tundra, grassland, or deciduous forest. The result: Over the course of civilization, land-use changes have liberated about 185 petagrams of carbon—an amount equal to about 75% of that released by burning fossil fuels, the researchers report in a paper in press at *Global Biogeochemical Cycles*. About one-third of the carbon released from altering land happened before 1850, judging from a different research group's estimate of carbon released since then. "It's a very reasonable" conclusion, says Running, who says the number may be even higher according to his own calculated map of prehistorical vegetation.

This dubious legacy of land destruction is, ironically, a boon today: In the United States, for example, regrowth of forests is sucking up a good chunk of the country's fossil fuel emissions (*Science*, 23 July, p. 544). Nowadays it's the tropics where land use is pumping out carbon instead of socking it away. But Field says that's no reason for northerners to gloat: "That doesn't make [today's reforestation] a virtuous thing."

Knowing how much carbon has been lost by altering landscapes also "sets the outer boundary of what reforestation is possible," says Field, because "in concept, the [losses] could be reversed" if in some cases countries can let farmers' fields grow back to their natural state. –**JOCELYN KAISER**

HYDROLOGY

Scarcity of Rain, Stream Gages Threatens Forecasts

Hydrologists warn that the world's network of rainfall and stream gages—often a low priority in science budgets—is slowly eroding

BIRMINGHAM, U.K.—On 1 March 1997, northern Kentucky was drenched with up to 25 centimeters of rain. The Licking River, which meanders through the town of Falmouth, rose a meter in only 3 hours and kept on rising. By evening, Falmouth's emergency siren was wailing and police were shouting evacuation orders through bullhorns. Most of the 2400 residents managed to flee, but the water came so fast, even shoving houses off their foundations, that some had to be rescued from rooftops. Four people in mobile homes drowned.

The river had crested 4 meters higher and 6 hours earlier than the National Weather Service (NWS) had predicted. NWS officials admitted that they had underestimated the danger, but added that their forecasts had been severely hampered by the loss of a crucial gaging station 32 kilometers upriver, which was cut in a budget crisis in 1994. "It was like a flash flood," says Mark Callahan of the NWS's Louisville office. "Without that gage, we were blind."

This kind of uncertainty is not unique. Around the world, the gages that measure rainfall and stream height are slowly disappearing, victims of a slow erosion in funding, according to hydrologists gathered here for the International Union of Geodesy and Geophysics from 19 to 30 July. At the meeting, some 400 hydrologists of the International Association of Hydrological Sciences (IAHS) issued a resolution calling rain and stream gages "an endangered species" and decrying "a severe decline in total quantity of data being collected worldwide."

That decline means that at a time when global warming may be exacerbating weather extremes and water shortages, scientists are less able to monitor water supplies, predict droughts, and forecast floods than they were 30 years ago, says John Rodda, president of the IAHS. And although remote sensing and other technologies offer new sources of climatic data, rain and stream gages remain crucial. "There really isn't any other way of finding out how much water is flowing down a river," says Ed Johnson, NWS's director of strategic planning in Silver Spring, Maryland.

Flooded out. Stream gages like this one near Juliette, Georgia, suffer wear and tear in extreme weather.

Individual gages aren't terribly expensive when compared to, say, a satellite—new U.S. river stations cost about $35,000 to install and $10,000 a year to maintain and operate. But even in countries with robust science budgets, maintaining aging gages is often low priority, especially when the weather's good. "If you go too long without a flood, people tend to lose awareness of the risk," says Duncan Reed, a modeler at the Institute of Hydrology in Wallingford, U.K. "They ask 'Why are we spending this money?' " Yet scientists need decades of continuous data to predict extreme events such as floods or drought, says Reed. Compounding the problem is the fact that the most critical gages, such as those that monitor rainfall or snowpack in mountains, are often remote and expensive to maintain; therefore they tend to be shut down first. When that happens, says Rodda, "you have the least information from the places you most need."

Many of the countries whose hydrological networks are in the worst condition are those with the most pressing water needs. A 1991 United Nations survey of hydrological monitoring networks showed "serious shortcomings" in sub-Saharan Africa, says Rodda. "Many stations are still there on paper," says Arthur Askew, director of hydrology and water resources at the World Meteorological Organization (WMO) in Geneva, "but in reality they don't exist." Even when they do, countries lack resources for maintenance. Zimbabwe has two vehicles for maintaining hydrological stations throughout the entire country, and Zambia just has one, says Rodda.

In South Africa, although the river gaging system is intact, the number of rainfall stations has plummeted from more than 4000 to about 1700. This is due in large part to urbanization, because daily rainfall reports typically come from farmers. "People are not inclined to do this service free of charge anymore," says Gerhardus Schulze, director of the South African Weather Bureau.

And in countries of the former Soviet Union, the problem is decentralization. The central Soviet hydrological service once collected all rainfall measurements and other data, but the new national hydrological agencies of countries in central Asia have much smaller budgets, notes Manfred Spreafico, director of hydrology with the Swiss Bundesamt für Umwelt, Wald und Landschaft in Berne. About 90% of the stations in the Aral

CREDIT: USGS

Sea region are broken or idle; that means "it is now much more difficult to estimate water resources than it was 20 years ago," says Rodda.

As for the United States, the problem is in river gages, which have dropped by about 6% over the last decade. Most of these stations are paid for with collaborative agreements between the U.S. Geological Survey (USGS) and more than 800 state and local agencies, but local priorities often shift, leading to loss of gages with long-term data, says Robert Hirsch, chief hydrologist at the USGS.

What's more, U.S. stations that record flow on small, free-flowing rivers have dropped by 22% since 1971. These stations are funded solely by the USGS, which has seen its gage budget shrink 9% in the past decade. The loss is "disturbing," says Hirsch, especially because these naturally flowing rivers show how streams respond to changes in land use and climate, and so are vital to climate models.

International officials have begun to address the problem, with several initiatives already under way. The World Bank has agreed to finance 25 new stations in Uzbekistan for a total of $2.5 million. And the World Hydrological Cycle Observing System, a program launched by WMO in 1993, is establishing 50 new monitoring stations in 10 countries in southern Africa. In the United States, Hirsch says he's beginning to see signs that Congress takes the problem seriously, and he hopes that next year's budget will include a $2.5 million boost for gages.

But even with new stations, coverage in the developing world will be sparse. And in the meantime, valuable climatic records are not being kept, says Schulze. "There is going to be a 10- to 20-year gap; it's data lost forever." For towns like Falmouth—where the upriver gage is still out of action—the losses might be even greater.

–ERIK STOKSTAD

CELL BIOLOGY

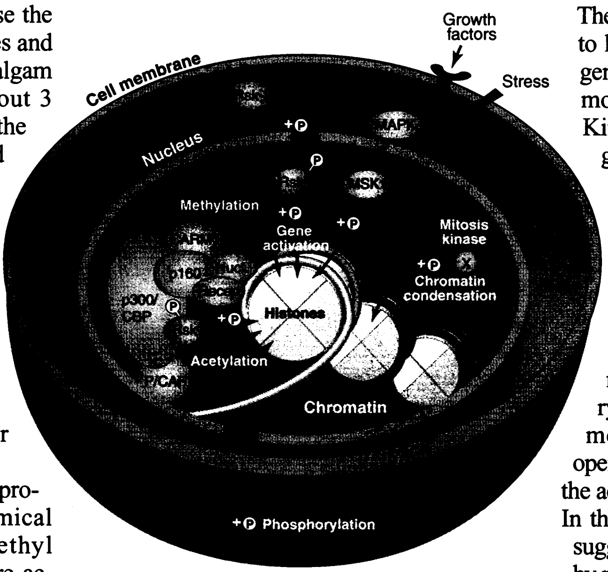
How Chromatin Changes Its Shape

A variety of modifications affect the protein-DNA complex known as chromatin, causing it to loosen—or tighten—as needed for cell function

Buried in the depth of the cellular nucleus, the long threads of DNA are the ultimate control center of the cell. But how the many molecular players that convey to the genetic material the signals it needs to determine what to do has been a mystery, because the DNA is literally balled up with histones and other proteins in a tightly wound amalgam known as chromatin. Beginning about 3 years ago, cell biologists discovered the first crack in DNA's armor. They found that when a small chemical entity called an acetyl group is glued to specific places on the histone proteins, the chromatin fiber opens up, allowing the cell's gene-reading apparatus to gain access to the genetic material (*Science*, 10 January 1997, p. 155). New work is now revealing other ways in which histones can be coaxed to loosen—or tighten—their grip on the DNA.

In recent months, researchers have produced evidence that two other chemical appendages—phosphate and methyl groups—can also make the DNA more accessible when they are attached to histones, boosting the activity of specific genes. One of those modifications, histone phosphorylation, also appears to be involved in other types of chromatin remodeling, such as the chromosome condensation that takes place prior to cell division. How the phosphorylation can have such different effects—opening up the chromatin for gene expression, but condensing it for cell division—is still an open question. But the finding suggests that histone modifications may have an impact far beyond gene activation.

"There's no reason to believe that a lot of these [chromatin-remodeling] activities won't function in other processes," such as DNA replication, recombination, or repair,



The center of attention. To open up the chromatin so that gene expression can occur, some transcription factors and coactivators attach different chemical tags such as acetyl or methyl groups to certain histone proteins. Similarly, growth factors, stress, and other external signals lead to histone phosphorylation to activate the appropriate response genes. But histone phosphorylation is also a driving force behind the condensation of chromatin into the densely packed chromosomes needed for proper cell division.

says biochemist Jerry Workman of Pennsylvania State University in University Park. Indeed, the findings point to a picture of chromatin as a kind of giant receptor complex that can pick up and integrate a variety of external and internal signals and can change its appearance accordingly—opening up to permit access or winding into tighter coils. "It's like a Morse code where the different modifications could work in various combinations to bring about a biologically meaningful response," suggests biochemist C. David Allis of the University of Virginia, Charlottesville, whose team is at the forefront of the work.

The two faces of histone phosphorylation

The first clue that adding phosphate groups to histone might alter chromatin and allow genes to be expressed came in 1991 from molecular biologist Louis Mahadevan of King's College in London. When certain growth factors stimulate cells, their signals are transmitted to the nucleus through the so-called MAP (mitogen-activated protein) kinase cascade—a series of kinase enzymes, each of which activates the next kinase in line by adding phosphate groups to it. Mahadevan observed that one of the five major histone proteins, H3, is phosphorylated as a result of growth factor treatment, and speculated that this change opens up the chromatin structure and allows the activation of the growth-promoting genes. In the years since, more and more evidence suggesting that MAP kinases activate genes by phosphorylating histones trickled in from Mahadevan, as well as from James Davie's lab at the University of Manitoba in Winnipeg. It took researchers several years to piece together what exactly was happening at the very end of the cascade, however.

One clue came from Allis and his colleagues. In the course of other work on histone phosphorylation, they had generated an antibody that recognizes H3 only when it has a phosphate on a specific amino acid, serine 10. When the researchers tested the antibody on growth factor–stimulated cells, they saw that it clustered in some 100 sharply

ILLUSTRATION: K. SUTLIFF