



**Vegging out.** In arid northwest Bangladesh, gardens are catching on as a simple way to compensate for declining rice yields.

CLIMATE CHANGE

# Hot, Flat, Crowded— And Preparing for the Worst

In a clarion call to other developing nations, Bangladesh is girding itself against the hazards of a warmer world

**RAJSHAHI, BANGLADESH**—Pale-green sprouts of summer rice are just poking up from water the color of milky tea pooled behind low earthen banks. These terraced rice paddies are a traditional farming method for coping with monsoon downpours. Another age-old adaptation of this community in northwest Bangladesh is *deowal bari*: thick mud walls that keep homes cool even as temperatures outside soar above 40°C.

But a changing climate is forcing locals to further improvise—and fast. This region of Bangladesh in recent years has received only about half the winter rainfall it averaged over the past half-century. Farmers here are often unable to sow winter crops. Compounding these woes, monsoon rains came nearly a month late in 2009, cutting short the main growing season. “Between May and December, we used to plant two rice crops,” says Alfaz Hossain, a local farmer. Now, he says, they plant only one. That has forced villagers to largely rely on a single harvest of *aman*, or “summer rice,” all year long.

Conditions are expected to deteriorate. The first high-resolution model of South Asia predicts that if average temperatures rise about 3°C by 2100, monsoons will rev up 2 weeks later than they do now, and rain will come in less frequent but more intense bursts, climatologist Noah Diffenbaugh of Purdue University in West Lafayette, Indiana, and colleagues reported in the 3 January issue of *Geophysical Research Letters*. That’s bad news for a country that gets ham-

mered regularly by floods, cyclones, and droughts. Bangladesh is “nature’s laboratory for natural disasters,” says Ainun Nishat, senior adviser at the International Union for Conservation of Nature’s Dhaka office.

Now Bangladesh is striving to become a global showcase for climate change adaptation. Earlier this month, its government approved a wide-ranging strategy for dealing with climate change that includes ramping up civil engineering projects to control flooding and protect farmland from rising sea levels. Researchers here are also testing crops that better tolerate floods and drought.

Realizing that time-honored approaches to living off the land no longer suffice, Bangladesh has implemented more community-level projects than any other country to gird people for climate shifts. With support from Livelihood Adaptation to Climate Change, a program run by the United Nations

(U.N.) Food and Agriculture Organization and Bangladesh’s Department of Agriculture Extension, farmers in Basuldanga, in the northwest, have been testing new ways to eke out a living. With program-supplied seeds and pointers from agricultural field officers, once-bare patches between houses are brimming with vegetables such as spinach and gourds watered from newly dug ponds that collect rainwater. There are now so many gardens, agricultural officers refer to Basuldanga as *subzee gram*, or “vegetable village.” “Vegetable cultivation can’t replace the loss of paddy [rice], but it provides a little bit of help,” says local farmer Mohammed Mostafa.

Given the uncertainties of climate modeling, “improving overall resilience is the way to go,” says Neil Adger, head of adaptation research at the Tyndall Centre for Climate Change Research in Norwich, U.K. He and others are calling for adaptation measures in Bangladesh and elsewhere that help people regardless of how the climate changes. There’s little time to spare. “We are running, but the climate is running faster,” says Habib Mohammad Naser, a soil scientist at the Bangladesh Agricultural Research Institute in Dhaka.

## Averting hunger

The U.N. has so far amassed about \$350 million in four funds to help high-risk locales adapt to climate change, including pilot efforts to fight malaria in Colombia and to strengthen shorelines on Kiribati, a Pacific island nation. But this funding is a thimbleful of what’s needed: The World Bank estimates that as much as \$100 billion a year is required to prepare people in vulnerable areas for climate change. That’s assuming the world gets its act together to rein in greenhouse gas emissions. If not, says disaster



**Old and new.** Thick mud walls of homes are a time-honored adaptation to scorching heat, while newly dug ponds collect rainwater for irrigation.



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expert Ian Burton of the University of Toronto in Canada, “then the cost of adaptation is going to be enormous.”

Although Bangladesh had been working on adaptation plans for several years, 2007 was a wake-up call. That year, after two severe floods and a cyclone, rice production overall fell 10% short of need; in some districts half or more of the crop was wiped out. Bangladeshis waited in long lines for government handouts, and food riots broke out.

Climate change presents many challenges for South Asia, but in Bangladesh, not surprisingly, “agriculture will be the hardest-hit sector,” predicts Sheikh Ghulam Hussain, an agricultural scientist with the Bangladesh Agricultural Research Council. Although the country’s rice production nearly tripled with Green Revolution techniques—improved seeds, more irrigation, and more fertilizer—progress here, as across much of Asia, has stalled. Bangladesh must ratchet up yields by at least 40% by midcentury to keep its population fed, says Hussain.

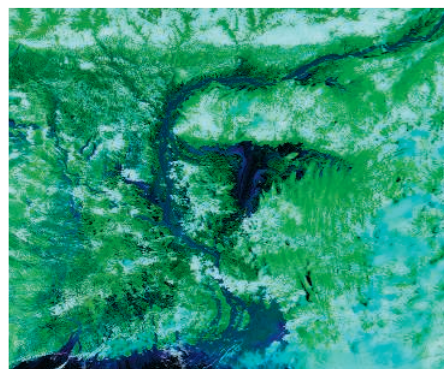
For more than a decade, Hussain has been modeling the effect of hotter weather and higher carbon dioxide levels on crops. An average annual temperature rise of up to 2°C above present day will have a negligible effect on rice in Bangladesh, his models predict. “But if it goes beyond that, to three or four degrees, then it will be a problem” for rice, says Hussain, who forecasts roughly a 25% decrease in rice production.

Raising production in a warmer climate will be a huge challenge, Hussain says, “but there are many options,” including improved crop varieties, shifts to new crops such as maize, and more efficient fertilizer use.

One promising development is rice that can withstand being underwater for days on end (*Science*, 18 July 2008, p. 330). Since severe floods often swamp Bangladesh, plant physiologist Jiban Krishna Biswas of the Bangladesh Rice Research Institute (BRRI) in Dhaka and colleagues are testing how rice responds to floods simulated in swimming pool-sized concrete tanks. Varieties with the gene *sub1* can survive 2 weeks underwater—more than twice as long as ordinary rice. The gene slows the plant’s growth to conserve energy and preserve chlorophyll, allowing it to spring back once floodwaters subside. One variety, Swarna *sub1*, could be ready for farmers in 2 or 3 years, says Biswas. “It would be a breakthrough,” he says, because Swarna *sub1* could be suitable for up to 1 million hectares, or one-sixth of Bangladesh’s summer rice.

BRRI researchers have also developed a rice variety called BRRI Dhan 47 that can

withstand high salt levels, and they are experimenting with aerobic rice, in which no standing water remains on a field, cutting water use in half. But scientists are making fewer inroads into traits such as tolerance to drought and heat. Therefore, Hussain argues, the main threat to rice from a warming world is sterility: When rice plants flower in summer, temperatures above 35°C for more than 8 hours straight often sterilize the plant’s spikelets, preventing these from developing into rice grains. “Once this



**Inundated.** Much of Bangladesh’s cropland (top) was deeply flooded after intense monsoon rains in July 2007 (bottom).

threshold is crossed, we will be in trouble,” Hussain says. Developing varieties that flower earlier in the morning could help avoid this problem, but the genes controlling flowering time haven’t been identified.

### Turning back the tide

The need for hardier rice, particularly salt-tolerant varieties, will only grow. As climate changes, a broad swath of Bangladesh is expected to grow saltier, and some areas could even disappear under the waves. Nearly a fifth of Bangladesh sits less than a meter above sea level; recent estimates forecast sea level rises of up to 2 meters by 2100 (*Science*, 5 September 2008, p. 1340). In Bangladesh, “river waters will be more saline, and the people will find that their lands are no longer suitable for agriculture.

They will lose their livelihoods,” predicts S. M. Mahbubur Rahman of the Institute of Water Modeling in Dhaka. Bangladesh’s climate change strategy warns that “sea-level rise could result in the displacement of millions of people.”

To blunt the ill effects, Bangladesh’s adaptation strategy calls for a Dutch-style overhaul of coastal polders: pockets of land enclosed by several-meter-tall earthen embankments that protect against high tides and moderate storm surges when cyclones tear through. Engineers have already built an extensive network of such embankments. Bangladesh’s plans call for extending, strengthening, and building them higher.

The integrity of inland embankments is also a major worry. Although torrential downpours fill rice paddies—an essential part of the agricultural cycle—too much rain can lead to flooding that wipes out crops. In 1998, the worst year on record, about two-thirds of Bangladesh was deep underwater, some places for as long as 2 months.

Seasonal flooding seems to have worsened in recent years, says climate scientist M. Monirul Mirza of Environment Canada in Toronto. Severe floods, in which more than a third of the country is inundated, hit five times between 1987 and 2007, compared with just twice in the previous 2 decades, he says. With a 2°C average global temperature rise, one of Mirza’s studies predicts, more intense monsoon rainfall would increase the area in Bangladesh hit by severe floods by at least 25%. Sea-level rise would compound the problem by slowing river flow, resulting in deeper and longer-lasting floods.

Bangladesh’s climate change strategy estimates that strengthening embankments and other adaptation projects would cost about \$5 billion over the first 5 years. So far, the government has contributed \$70 million to a trust fund to pay for the work, says S. M. Munjurul Hannan Khan, deputy secretary of the Ministry of Environment and Forests, and other countries have pledged contributions, including \$30 million from the United Kingdom.

Grassroots efforts are critical. “It’s necessary for officials to learn from farmers and pass information up to research scientists and planners,” says U.K. soil scientist Hugh Brammer, who for more than 40 years has helped Bangladesh shape its strategy for agriculture and flood control. If Bangladesh’s recipe for adaptation works, it may end up being emulated as other countries brace for the consequences of a warmer world.

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