CLIMATE CHANGE AND AGRICULTURE

Modest Advances, Stark New Evidence

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THE YEAR 2011 BROUGHT BOTH GOOD AND bad news about climate change and agriculture. The good news is that after initial steps toward rebuilding confidence in the United Nations' climate change negotiations were taken in Cancun in December 2010, further progress occurred in Durban in 2011. And outside the formal negotiations process, many countries have begun to implement their own mechanisms to reduce greenhouse gas emissions and to adapt to some climate changes that increasingly seem inevitable.

The bad news includes growing evidence that climate change has already affected agricultural productivity[1] and will put increasing pressure on agriculture in the coming decades. Recordbreaking extreme weather events around the world in 2011 offered a glimpse of the challenges climate change will bring. Farmers worldwide will need to adapt to higher temperatures and shifting precipitation patterns. In addition, climate variability will likely cut into global food production, exacerbating the existing problems of poverty, food insecurity, and malnutrition. In addition, after declining in the wake of the global financial crisis, greenhouse gas emissions are once again rising rapidly, making the climate change challenge to food security much greater.

REBUILDING CONFIDENCE IN INTERNATIONAL NEGOTIATIONS, SLOWLY

Delegates to the United Nations Framework Convention on Climate Change arrived in Copenhagen in December 2009 with great optimism that an agreement could be reached to reduce greenhouse gas emissions and provide

financial support to help developing countries adapt to climate change. Most of the world's leaders were scheduled to arrive in the second week, when they would undertake the final political negotiations needed to close the deal. As the second week arrived, however, a deal was nowhere

BOX 5

Better Tools for Tackling Climate Change

Bruce Campbell, CGIAR Research Program on Climate Change, Agriculture and Food Security

Farmers and policymakers in developing countries need support in their struggle to adjust to global changes in climate. They must have evidence to weigh the pros and cons of different strategies and policies. Providing that support through research-based evidence is the goal of the CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS), which was in its first full year of operation in 2011. Inevitably, adjusting to climate change will mean making complex tradeoffs among food security, livelihoods, and the environment both at grassroots levels and in the corridors of power. Sound research will help policymakers, farmers, and others affected by climate change understand the implications of their decisions when making difficult compromises.

Progressive climate change threatens farmers in developing countries, who must adapt their farming practices to the changes ahead in order to survive. Studies by CCAFS Program scientists published in the book *Crop Adaptation to Climate Change* describe how climate change could threaten production of important food crops such as potatoes, beans, bananas, and cassava—and how specific adaptation strategies such as new plant breeds could neutralize or at least significantly lessen the impact.[1] As part of the Program's work on adaptation through managing climate risks, researchers have been training farmers on interpreting seasonal climate forecasts in East and West Africa. The Program's researchers also produced a study on "Mapping Hotspots of Climate Change and Food Insecurity in the Global Tropics" to identify food insecure areas most vulnerable to the impacts of future climate change, across the priority regions for the CGIAR centers.[2] A workshop and paper series examined how new institutions, property rights arrangements, and agricultural technologies can improve livelihoods and reduce greenhouse gas emissions.[3] As part of its ongoing work on gender, the Program issued grants to six female scientists working in Program target regions to study the links among gender, climate change, agriculture, and food security.[4]

Climate change was on the agenda of many international institutions in 2011, including two large conferences: the United Nations Framework Convention on Climate Change in Durban, South Africa, and the International Conference on Climate Change and Food Security in Beijing, China. Key agricultural organizations (including the Program, the World Bank, and IFAD) coordinated Agriculture and Rural Development Day, a parallel event at the UN conference that focused on galvanizing international support for a new work program on agricultural climate change adaptation and mitigation.

The Program's work in 2011 focused on taking stock and developing the relevant research strategies that will have the greatest impact. For example, researchers implemented a baseline food security and climate adaptation survey covering more than 5,000 households in more than 250 villages across 36 sites in 12 countries in East and West Africa and South Asia.[5] The data gathered in the past year will help provide decisionmakers with evidence-based results and useful tools for designing and testing approaches to adaptation and mitigation. When their work is completed, researchers will be able to report whether certain techniques were successful. The Program has also created the Climate Change Adaptation and Mitigation Knowledge Network, an information service and a key tool for practitioners, donors, policymakers, and researchers interested in food security and climate change. The Network is a map-based online platform that brings climate, agriculture, and socioeconomic information together, and uses multimedia to share stories of farmers living at research sites across the tropics.

Climate change affects agriculture and food security in a variety of ways, so choosing the best mitigation and adaptation techniques requires thorough research. The CGIAR Research Program on Climate Change, Agriculture and Food Security contributed significant evidence in 2011, but this is only the beginning of an undertaking that must reach beyond a single research program to match climate change's complexity with its own breadth and depth.

in sight. The impending arrival of several political leaders on Friday, the official closing day, meant that negotiators needed to engage in extremely high-level talks to develop some kind of agreement. After several sleepless nights, the negotiators took note of a document called the Copenhagen Accord, emanating from several high-level meetings. This accord enshrined the goal of keeping the average temperature rise to 2°C and pledged US$10 billion a year from developed countries over the next three years, rising to US$100 billion a year by 2020, to help poor countries adapt to climate change. None of these commitments, however, were binding, and it is unclear that any have been or will be met.

Although the Copenhagen negotiations were unsuccessful overall, they marked the start of a push to formally include agriculture in the negotiation outcomes, with the first Agriculture and Rural Development Day providing a convening venue for those concerned about the challenges to agriculture from climate change. Buttons bearing the slogan "No agriculture, no deal!" made their first appearance and have become an increasingly common sight at United Nations negotiations.

At the following year's convention, delegates arrived in Cancun in late November 2010 with greatly lowered expectations and no plans for the attendance of large numbers of heads of state. With low expectations as a starting point, the eventual outcomes were substantial. Negotiators approved a large number of documents, collectively called the Cancun Accord. Important elements included the reaffirmation of the 2°C temperature increase target, improved reporting requirements, and the start of a process to design a Green Climate Fund. The second Agriculture and Rural Development Day was held, with delegates pushing negotiators to formally include agriculture in any outcomes and calling for approval of an official work program on agriculture. Unfortunately, the work program was lost in the final days of the negotiations when it got caught up in disagreements about whether individual sectors should be singled out and a perception by some negotiators that a work program would focus only on mitigation and ignore adaptation.

The 2011 Durban round of negotiations was widely perceived as particularly important for Africa, because a successful outcome would reflect well on the continent and because Africa is likely to be seriously affected by climate change[2] and so would have much to gain from a successful outcome. One of the key challenges was the pending expiration of the Kyoto Protocol in 2012. The protocol set binding targets for emissions for most developed countries (the United States was not a signatory and therefore not a party to the emissions reduction commitments). Without an extension of the protocol, countries would no longer be legally bound to reduce their emissions.

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With African agriculture especially threatened by climate change, a major push was made to persuade the negotiators to include an official work program on agriculture. The activities of the third Agriculture and Rural Development Day were organized around this goal, and major public figures, including former UN secretary general Kofi Annan and Jacob Zuma, president of South Africa, pressed the negotiators to approve the work program on agriculture.

By the last Friday of the negotiations, it was unclear whether anything would be achieved. But negotiators agreed to continue their work and extended their string of sleepless nights, ultimately finishing Sunday morning. The outcome of this effort is called the Durban Platform for Enhanced Action. A key element of the platform is that all Kyoto signatories plus the United States agreed to forge a treaty by 2015 that would bring all countries, developed and developing, under a legally binding agreement by 2020. For the first time, China and India, two of the world's largest emitters of greenhouse gases, agreed to this principle.

The Green Climate Fund was formally established and awaits contributions from member countries. A second commitment period for the Kyoto Protocol was approved with the reduction targets to be determined at a meeting in 2012. However, Canada, one of the important countries to sign on to the first commitment period, announced it would not join the second period, and other developed countries have suggested that they may follow suit. Finally, although the negotiators did not adopt an official work program on agriculture, they did approve a process for developing a work program for approval at the next negotiating session, to be held in Qatar beginning in late November 2012.

GOING IT ALONE: INCREASING PROGRESS OUTSIDE FORMAL NEGOTIATIONS

Although progress remains extremely slow in the official negotiating process, countries around the world are beginning to devote substantial resources to agricultural adaptation and mitigation activities that could have high payoffs today and lead to increased resilience tomorrow.

India

India continues to launch adaptation programs at both the national and state levels. Adaptation activities in different areas of the country include efforts to improve and diversify crops, conserve soils, develop watersheds, manage irrigation water, and improve disaster management through, for example, drought and flood proofing. An example of one of these activities is a community watershed project designed to explore low-cost water conservation solutions to improve crop yields in the face of drought in the community of Kothapally in Andhra Pradesh, India. This long-term project, developed by the International Crops Research Institute for the Semi-Arid Tropics at the request of the government of Andhra Pradesh, was designed with and managed by the community. A recent impact study showed that the project's water management practices improved infiltration and water-holding capacity of the soil, increasing water availability by 10 to 30 percent and raising crop yields. The study suggests that implementing agricultural water interventions on a large scale can significantly raise agricultural productivity and increase farmer livelihoods.[3] Still, more needs to be done to increase the adaptation of agricultural systems in India because climate change threats to productivity are expected to grow. Additional adaptation strategies—such as more efficient use of water, promotion of eco-friendly technologies, shifts in cropping patterns, and agricultural insurance—should be considered, and adaptation and mitigation programs should be mainstreamed into national agricultural strategies.

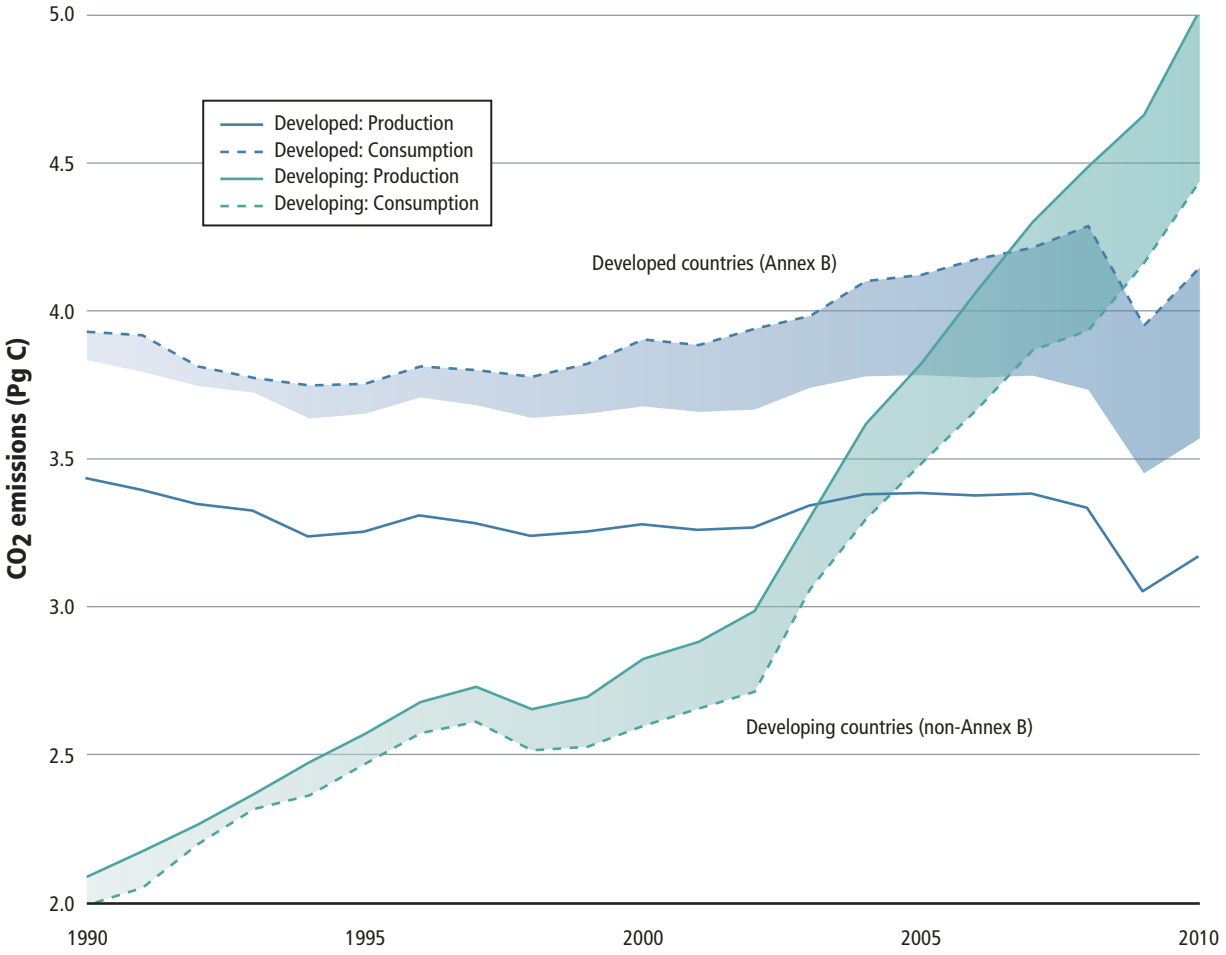
China

The government of China, which launched a national Climate Change Program in 2007, has explored several strategies and activities to help the agricultural sector adapt to climate change.[4] Some of the efforts include improvements to agricultural infrastructure and increased investment in research and development of new technologies. To improve agricultural infrastructure, the government has, for example, accelerated the construction of water-saving irrigation projects. As part of special funding arrangements established for climate change adaptation, China has invested in new technologies such as cloud seeding to promote reliable rainfall. The government has also increased pilot projects on different types of insurance policies. Because these efforts were initiated recently, their effectiveness has not been assessed and documented.

Kenya

A recent study of four agroecological zones in Kenya shows there are win-win-win agricultural practices that can pay off in terms of adaptation, mitigation, and profitability. For example, when poor smallholder producers use sustainable agricultural management practices, they not only increase their resilience to climate change and variability, but also contribute directly to reducing greenhouse gas emissions and increasing agricultural productivity and profitability. In particular, soil nutrient management—applying combinations of inorganic fertilizer, mulch, and manure—is

FIGURE 1 Carbon dioxide emissions in developed and developing countries, 1990–2010 (PgC)



Source: Figure 2 in G. P. Peters, G. Marland, C. Le Quéré, T. Boden, J. G. Canadell, and M. R. Raupach, "Rapid Growth in CO2 Emissions after the 2008–2009 Global Financial Crisis," *Nature Climate Change* 2, no. 1 (2012): 2–4, doi:10.1038/nclimate1332. **Note:** Carbon dioxide emissions are for fossil fuels.

shown to enhance crop yields, soil carbon stocks, and incomes from agricultural production. Similarly, introducing improved feeds for dairy cattle decreases methane emissions per liter of milk and increases profitability in most parts of Kenya. These improved practices can allow livestock producers to reduce the numbers of livestock and lower overall emissions while increasing food production and food security. In the arid zone, farmers can use irrigation and soil and water conservation methods to maximize soil carbon and agricultural profits. These win-win-win actions, however, have yet to be strategically exploited. To do so will require building capacity among decisionmakers at the national level to ensure that they explicitly include climate change adaptation and mitigation in their agricultural productivity and food security strategies and policies. It will also require improving farmers' access to financial resources, such as voluntary carbon markets and adaptation and mitigation funds.[5]

NEW EVIDENCE ON THE THREATS TO AGRICULTURE FROM CLIMATE CHANGE

To illustrate the challenges in mitigating greenhouse gas emissions, Figure 1 contrasts trends in domestic carbon dioxide emissions in developed and developing countries. For developed countries, emissions from domestic production have

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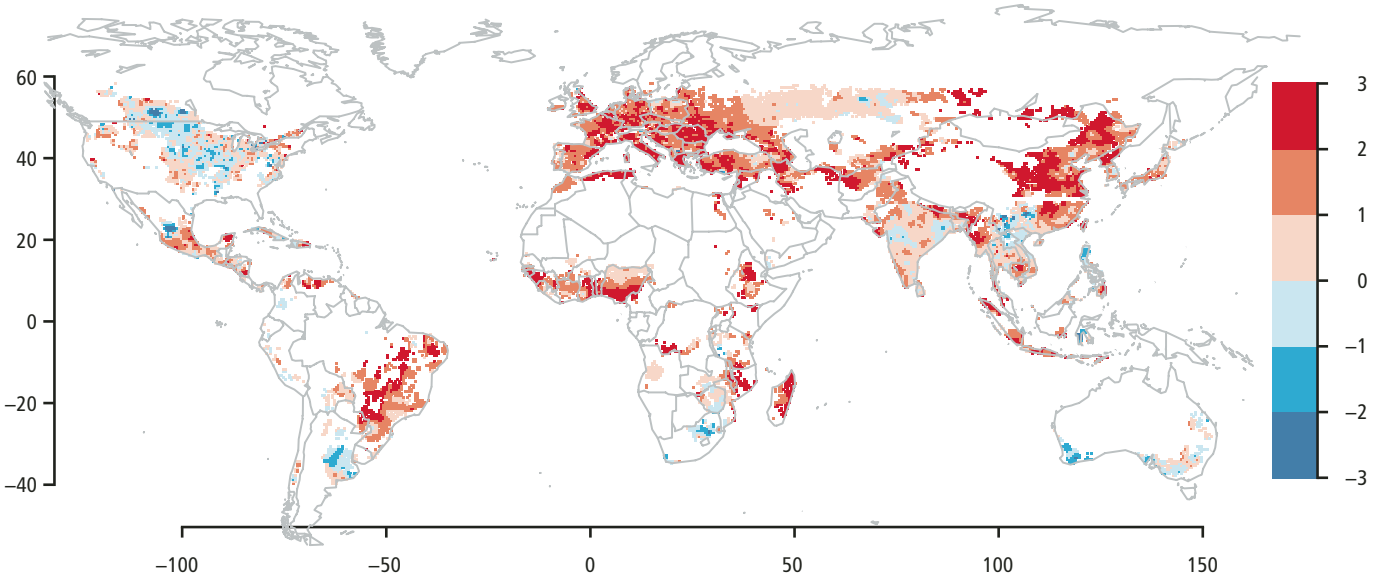
remained relatively flat for the past 30 years, with a large dip in 2008 as the global economic crisis reduced economic activity. Emissions from consumption have continued to grow in the form of emissions associated with imports produced in developing countries.

In stark contrast, developing-country emissions have grown dramatically, surpassing those from developed countries by the late 2000s. The green shaded area indicates that a significant and growing portion of developing-country emissions are from production for export to developed countries, but emissions from domestic consumption have surpassed those from developed-country consumption. This situation makes it increasingly obvious that developing countries should not be excluded from national commitments to reduce emissions, as they were in the Kyoto Protocol. As incomes in developing countries grow, they must pursue low-emissions development strategies.

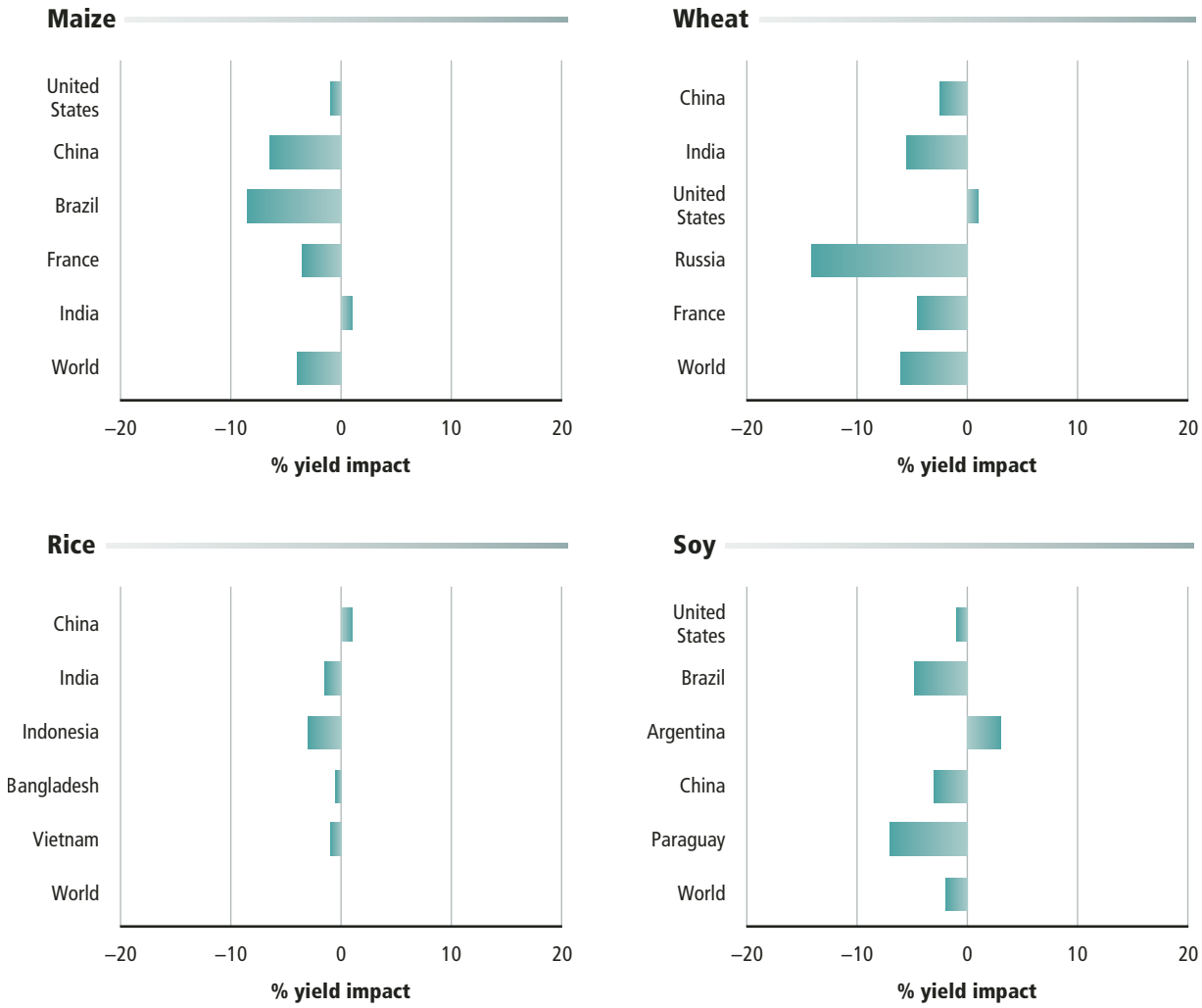
Climate scientists are increasingly confident of the link between recent anthropogenic emissions of greenhouse gases and rising temperatures such as those experienced in Iowa, in the heart of the US Corn Belt. Researchers have demonstrated the threat to US maize production from higher temperatures based on a detailed statistical analysis of actual maize yields from 1950 to 2005.[6] Their findings show that as average growing season temperatures rise to 28°C, yields are relatively little affected. However, once temperatures surpass the threshold of about 30°C, yields drop precipitously. Another study using extensive maize experimental data from International Maize and Wheat Improvement Center trials in Sub-Saharan Africa had broadly similar results.[7] Under optimal management, when the mean growing season temperature is less than 22°C, a 1°C increase in temperature has a small but positive effect on yields. But as the average growing season temperature exceeds 25°C, the effect becomes negative, causing roughly a 30 percent decline in yields. And during

FIGURE 2 **Change in growing season temperature, 1980–2008**



Source: Figure 1 in D. B. Lobell, W. Schlenker, and J. Costa-Roberts, "Climate Trends and Global Crop Production since 1980," *Science* 333, no. 6042 (2011): 616–620, doi:10.1126/science.1204531.

FIGURE 3 Estimated net impact of climate trends for 1980–2008 on crop yields, divided by the overall yield trend



Source: Figure 3 in D. B. Lobell, W. Schlenker, and J. Costa-Roberts, "Climate Trends and Global Crop Production since 1980," *Science* 333, no. 6042 (2011): 616–620, doi:10.1126/science.1204531.

a drought, the yield declines begin at lower temperatures and can be greater than 40 percent.

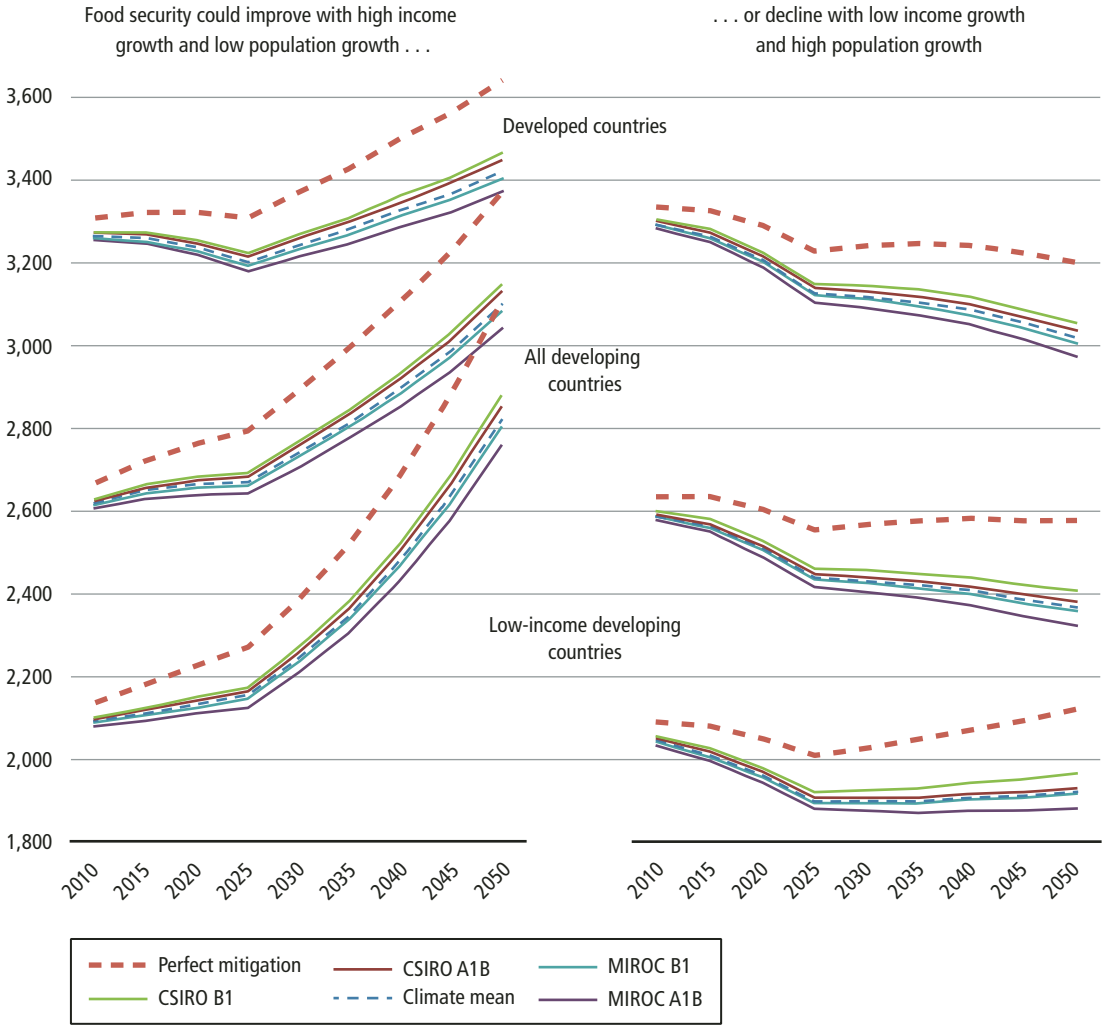
Other recent research strongly suggests that rising temperatures in the second half of the 20th century and early years of the 21st century, and accompanying changes in precipitation, have already had observable effects on agriculture. Although growing season temperature changed only slightly in North America from 1980 to 2008, it increased dramatically in other parts of the world, particularly China and Europe (Figure 2).

The consequence of the differing temperature increases can clearly be seen in the changes in yields (Figure 3). For maize, climate change had essentially no effect on US yield trends, whereas it substantially slowed yield growth in Brazil, China, and France. In some countries, however, regional crop production has benefited from higher temperatures. The growing area has shifted northward for maize in the United States, rice in China, and wheat in Russia.

THE CHALLENGE TO FOOD SECURITY

The precise temperature and precipitation changes that climate change will bring, as well as the

FIGURE 4 **Scenarios of climate change and food security**



Source: Figure 3.1 in G. C. Nelson, M. W. Rosegrant, A. Palazzo, I. Gray, C. Ingersoll, R. Robertson, S. Tokgoz, et al., *Food Security, Farming, and Climate Change to 2050: Scenarios, Results, Policy Options,* IFPRI Research Monograph (Washington, DC: International Food Policy Research Institute, 2010). **Notes:** The dashed red lines show calorie availability in an unrealistic scenario with perfect mitigation (that is, all emissions stop today and the existing momentum in the climate system is also stopped). The solid lines of various colors reflect outcomes with plausible climate results from two general circulation models, each with two scenarios, from the *Intergovernmental Panel on Climate Change's Special Report on Emissions Scenarios.* The shift in values in 2025 reflects the assumption that maize-based ethanol will be replaced with cellulosic ethanol around 2025. This change will reduce the demand for maize, lower its price, and make more calories available for human consumption.

context within which they will take place, are still uncertain. Consequently, to design policies that can protect populations vulnerable to climate change and increase the likelihood of achieving sustainable food security, it is critical to understand the impacts of climate change under different scenarios. Figure 4 shows how climate change will likely challenge food security. It reports average calorie availability per person per day—an imperfect measure of food availability—under a range of climate change scenarios and two overarching scenarios of the development context. The optimistic scenario reflects high income growth and low population growth, representing a situation of sustainable development. The pessimistic scenario consists of low income growth and high population growth.

Three messages stand out from the results in Figure 4. First, sustainable development, embodied in the optimistic scenario, is key to improving the

well-being of the poorest. With sustainable development, calorie availability improves dramatically in the 40 countries with the lowest income today. Second, climate change significantly reduces calorie availability around the world, as shown by the gap between a scenario of perfect mitigation and the rest of the climate change scenarios. Finally, although the different climate change scenarios have substantially different consequences for agricultural productivity, the final outcomes for calorie availability are similar. This result is due to dramatic differences in trade flows in the different scenarios. Thus, relatively open international trade will be a crucial part of adapting to climate change.

Rapidly increasing greenhouse gas emissions, especially in developing countries, combined with growing evidence of negative climate change effects on agriculture, the likelihood of nonlinear effects of temperature on yields, and hints of the added burden of more frequent extreme weather events suggest an extremely serious challenge for sustainable food security. Renewed efforts to reduce greenhouse gas emissions and redoubled efforts to develop crop and livestock varieties, along with management systems that remain productive with higher temperatures and more extremes in heat and precipitation, are crucial. In 2011, the body of evidence on the threat to food security from climate change became increasingly robust. The challenge is to find the resources to address the problems before they overwhelm us. ■