Agricultural Research and Climate Change:

Why CGIAR Science Is Relevant to the Needs of Poor Farmers

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As evidence mounts that the earth's climate is becoming warmer, the predicted effects of climate change on developing-country agriculture—for instance, on the productivity of crops, livestock, forestry, and fisheries—are of enormous significance to millions of small farmers, and the ecosystems on which they depend. In addition, these farmers can help mitigate global warming by sequestering carbon in their agricultural systems. Thus, global climate change is inextricably linked to the CGIAR's goals of food security, poverty reduction, and environmental protection.

Agricultural activities are cited as one of the leading causes of climate change, contributing some 20 percent of all greenhouse gas (GHG) emissions. For the CGIAR, the challenge of mitigating and adapting to climate change depends on knowing which ecosystems are at risk, gauging their levels of vulnerability, and knowing how and where the most carbon can be sequestered, and emissions of other GHGs minimized in differing ecosystems. Identifying and closing such "knowledge gaps" is key to mitigating, and adapting to, climate change.

To develop a coherent, systemic response to the challenges posed by climate change, and to enhance agriculture-related climate change research capacity within the CGIAR, an Inter-Center Working Group on Climate Change was established in 1998 under the leadership of the International Centre for Research in Agroforestry (ICRAF). CGIAR's climate change–research agenda aims to develop:

- Strategies to *mitigate* the accumulation of greenhouse gases (for instance, by increasing carbon stocks in agroecosystems, improving nitrogen-use efficiency and reducing nitrous oxide emissions, improving water-use efficiency, and promoting increased carbon sequestration through improved management of croplands, forests, and grazing lands)

- Strategies to *adapt* to the consequences of climate change (for instance, making crops, livestock, tree species, and their husbandry more efficient under changing climatic conditions; integrated gene management for enhancing germplasm for higher yields and better resistance to abiotic and biotic stresses; protection of *in situ* biodiversity; and development of tools to cope with erratic water resources)

- Better models to predict the *impact* of global climate change on tropical crops.

The Inter-Center Working Group on Climate Change has developed a portfolio of 11 research proposals, including mitigation and adaptation components. These include:

- Identifying hot spots for carbon removal
- Exploring soil carbon and nitrogen dynamics
- Measuring soil carbon at the project level
- Identifying carbon sequestration potentials in differing agroecosystems
- Increasing nitrogen-use efficiency to reduce nitrous oxides emissions to the atmosphere
- Studying carbon dynamics during the rehabilitation of degraded croplands, grasslands, and cleared forests
- Increasing carbon sequestration and minimizing methane and nitrous oxide emissions in rice farming
- Reducing methane emissions in semi-arid pastoral systems
- Building institutional capacities in developing countries on agricultural and climate change
- Pursuing carbon sequestration with a human face: offset projects based on smallholder farming communities in developing countries
- Conducting *ex ante* studies of the impact of CGIAR research on GHG emissions over the next 25 years.

One of the initial studies conducted by the working group was to assess the Green Revolution's impacts on global climate change. The results illustrate the positive effects of farm intensification on preventing additional global warming.

During the period from 1965 to 1995, high-yielding Green Revolution technologies "saved" 426 million hectares of land from being brought under the plow, thereby preventing the release of 570 megatons of carbon per year into the atmosphere. The beneficial effects of Green Revolution technologies apply to all the "culprit gases" that are responsible for global warming. For example, during the period from 1965 to 1995 carbon dioxide emissions from soil and vegetation were estimated at 202 megatons per year, compared to 766 megatons that would have been emitted without the new land-saving technology. Similarly, 7 megatons of methane were emitted, compared to 13 megatons of methane that would have been released into the atmosphere without the new technology. (There was no difference in the emission of nitrous oxide with or without the new technology.)

Smallholder farming is extremely susceptible to the vagaries of nature. A failed harvest can be a calamitous event, with severe economic and social repercussions for small farmers. Predictions are that poor countries will be hit hardest by global warming; several CGIAR research programs are focused on these vulnerable areas. For instance, CGIAR crop improvement programs are now incorporating the predicted future climates at key locations in their research programs. The following examples illustrate aspects of this work.

REDUCED TILLAGE IN RICE-WHEAT ROTATIONS CAN SAVE LARGE AMOUNTS OF CARBON EMISSIONS IN THE INDO-GANGETIC PLAINS

Under the aegis of an innovative program entitled the "Rice-Wheat Consortium for the Indo-Gangetic Plains," five Future Harvest Centers supported by the CGIAR are working with the national agricultural research programs of Bangladesh, India, Nepal, and Pakistan to investigate how low and reduced tillage practices in rice-wheat rotations can maximize yields, conserve soil and water, and contribute to the slowing of global warming.

The area under study (the Indo-Gangetic Plains) is the most intensely cropped agricultural land in the world, and a source of food and livelihood for nearly 1 billion people, many among the poorest of the poor in South Asia.

The potential beneficial results from some simple changes in land management are compelling. Widespread adoption of one or several reduced-tillage methods could annually save irrigation water (as much as 5 billion cubic meters) and diesel fuel (0.5 billion liters), and reduce pesticide use significantly. The fuel savings alone would represent an annual reduction of 1.3 million tons of carbon emissions—emissions that are the principal contributor to global warming. Furthermore, CGIAR scientists are working with farmers to minimize burning of crop residues, with the potential to further reduce annual carbon emissions by 17 million tons. All these gains are economic, environmental, and social win-wins.

The Centers involved in this innovative effort include the Centro Internacional de Mejoramiento de Maïz y Trigo (CIMMYT), the Centro Internacional de la Papa (CIP), the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), the International Rice Research Institute (IRRI), and the International Water Management Institute (IWMI).

USING FOREST CARBON CONTENT FOR SUSTAINABLE DEVELOPMENT

Climate change specialists have long agreed that forestry and land-use changes in the tropics are, on balance, large sources of greenhouse gas emissions. Efforts to reduce these net emissions through forest-based mitigation actions have included afforestation and reforestation, reduced-impact logging, forest conservation, and improved forest management.

Another Future Harvest Center, the Center for International Forestry Research (CIFOR), has been working on the management and use of forests to either sequester carbon or to reduce emissions of greenhouse gases to the atmosphere. Forests have much higher forest carbon stocks than most non-forested land uses, and can be either significant sinks or sources of greenhouse gases. Clearing a tropical forest for conversion to agriculture or agroforestry releases hundreds of tons of carbon into the atmosphere—and in many ways has the same atmospheric effects as the combustion of fossil fuels. CIFOR scientists are measuring potential carbon gains, either from avoided deforestation or

from planting trees in climate-action projects, and are evaluating the social and environmental impacts of these projects. Their research also focuses on the opportunities and risks to local communities, a major concern of environmental groups and governments. Preliminary results from this work have been presented as policy briefs which help to inform public policymakers about the need to increase economic opportunities for local communities, and to protect the livelihoods of people in areas where such projects would be implemented.

AGROFORESTRY—THE TOP CARBON SEQUESTRATION PRACTICE

Another promising area of CGIAR research is transforming low-productivity croplands to agroforestry systems. This effort, led by ICRAF, is demonstrating how conversion of unproductive croplands and grasslands to agroforestry has the highest potential to soak up maximum amounts of atmospheric carbon—at rates on the order of 3 tons of carbon per hectare per year. This conversion occurs in the process of replenishing the soil fertility of smallholder farms in Sub-Saharan Africa, and in implementing tree-based alternatives to slash-and-burn agriculture at the margins of the humid tropical forests worldwide. The potential contribution of converting degraded croplands and grasslands into agroforestry systems is predicted to be 390 million metric tons of carbon per year by the year 2010.

PREDICTING THE IMPACT OF GLOBAL CLIMATE CHANGE ON TROPICAL AGRICULTURE

Scientists at two Future Harvest Centers—the Centro Internacional de Agricultura Tropical (CIAT) and the International Livestock Research Institute (ILRI)—have developed and tested a new approach for predicting the impacts of global climate change on specific crops grown in the tropics. MarkSim, a new software package that uses a Markov rainfall model to simulate weather data, can predict day-by-day rainfall and temperature information for any point in Africa, Asia, or Latin America. Agricultural decisionmakers in those three continents will be able to use MarkSim output to better plan mitigation measures, and counter the effects of global warming on farming communities and urban food supplies. MarkSim draws on long-term input from 9,200 weather stations around the world; comprehensive testing shows MarkSim can deliver robust results, even for those areas where weather data have not been collected.

MarkSim is showing considerable promise in mapping yield probability of staple crops. As part of a case study in quantifying the effects of global climate change on tropical agriculture, scientists from CIAT and ILRI applied MarkSim in combination with two other well-known classes of computer models. The results follow.

First, the results from the Hadley General Circulation model (which conservatively predicts average temperatures in the tropics to rise 3 degrees Celsius over the next 30 years) were matched with simulated weather data from MarkSim for southern Africa (including Zimbabwe and most of Mozambique and Namibia). Next, the results were fed into reliable crop models to simulate the weather effects on maize and pasture growth in the targeted region. The picture that emerged from preliminary modeling results depicts increasingly risky agriculture, with dire consequences for small farmers. In most areas, the model predicted marked decreases in the yields and yield-stability of maize and pastures. The modeling exercise has potential applications to all CGIAR-mandate crops.

While other approaches have been able to discern these downward trends in yields, the CIAT and ILRI approach—unique in its ability to interpolate daily weather data—establishes the future probability of dry spells that can adversely affect yields, and, ultimately, human well-being. The challenge will be to incorporate information and output from tools such as MarkSim into long-term planning of agricultural research and development aimed at providing farmers with new options for coping with climate change.

As the above examples show, global climate change is inexorably linked to the CGIAR's goals of food security, poverty reduction, and environmental protection. As a strategic, knowledge-intensive organization, the CGIAR has a major responsibility to bring the drivers of global climate change into the agricultural research and capacity-building agenda. Ultimately, the developing countries that bear a disproportionate burden of the negative effects of global climate change will benefit.