

## **Getting the Better of Global Climate Change** *A New Strategic Initiative in the CGIAR*

*The 15 Centers supported by the Consultative Group on International Agricultural Research (CGIAR) are engaged in a wide range of tasks that are fundamental for enabling developing country agriculture to adapt to and mitigate the expected impacts of global climate change. These tasks lie at the heart of the CGIAR's mission to reduce hunger and poverty and improve the management of natural resources in developing countries. The purpose of this document is to provide an overview of that research in connection with a new strategic climate change initiative, which the CGIAR will announce on December 8, 2007, at the 13<sup>th</sup> UN Climate Change Conference in Bali, Indonesia. The initiative will call on the international community to support the CGIAR's efforts to intensify climate change research, and substantially increase resources dedicated to this vital work. In 2006, the CGIAR's combined expenditures on climate change amounted to nearly US\$70 million, or 15 percent of its total budget.*

### **Building on a Wealth of Experience and Expertise**

Global climate change poses an ominous threat to food security and to rural livelihoods in the developing world. On this point, scientists are now universally agreed, though some uncertainty remains about the magnitude of the damage that can be expected. In any case, farmers in the tropics and subtropics will see fundamental changes in rainfall patterns as well as rising temperatures, which will intensify pest outbreaks and reduce crop productivity. Further damage will come from more severe and frequent extreme weather events, such as drought and flooding. At some locations, those trends are already in evidence.

The particular vulnerability of agriculture in developing countries is now well understood, in large part thanks to the important efforts of the International Panel on Climate Change (IPCC). Among the many specialists who helped the IPCC craft its central messages (conveyed through a series of reports released in 2007) were dozens of scientists working in the 15 Centers supported by the CGIAR (see annex).

For this purpose, CGIAR scientists drew upon a wealth of experience and information, together with powerful analytical tools. Much of their work, carried out in collaboration with numerous partner organizations, has been aimed at helping poor farmers achieve sustainable rural livelihoods, despite variable and severe weather, together with increased pressure on agriculture's natural resource base. Through this work, the Centers have built strong capabilities and comparative advantages in three main areas:

- Gauging the vulnerability of agriculture, natural resources and rural communities
- Breeding crops for stress tolerance, while developing better practices for sustainable crop and environmental management
- Supporting the development of policies that are conducive to sustainable agricultural growth

Building on those strengths, all 15 CGIAR Centers have assigned climate change a central place in their research efforts, and some have set up programs dealing exclusively with this theme. As a result, the Centers are now poised to greatly intensify current research – essentially doubling the resources dedicated to this effort (see table) – under a new strategic climate change initiative.

The following sections inventory CGIAR research that will constitute the main building blocks of the new initiative, emphasizing the value and key components of the research as well as future imperatives.

### **Assessing the Impacts of Climate Change**

The impacts of global climate change on agriculture and natural resources will vary greatly over time and across locations, depending on different agroecologies, production systems and even particular plant and animal species.

CGIAR scientists have progressed significantly – with the aid of geographical information system (GIS) technology and simulation models – in determining what consequences rural people, especially the poor, can expect to face at specific locations in the coming decades. GIS consists of computer-based programs that bring together and analyze information from diverse sources and present the results in map form. When linked with computer models simulating changes over time and space in crops, landscapes, weather and other complex systems, GIS offers a powerful means of predicting and visualizing likely futures for plants, people and places. The maps produced by GIS can provide an early warning as to which of these are at greatest risk and where.

The information resulting from such analysis will be essential for targeting strategies and measures aimed at helping rural people cope with climate change and for adjusting these interventions to variable circumstances in diverse landscapes. CGIAR research thus has huge potential for providing detailed and reliable guides to local action in the development of strategies for adaptation to climate change.

### ***Research in progress***

CGIAR scientists have analyzed the expected effects of climate change on the productivity of major staple crops in the tropics and subtropics. Specifically, they have focused on maize in all of Latin America and sub-Saharan Africa and wheat in a key production environment that is heavily concentrated in South Asia. These studies involved the use of world daily climate data and downscaled GCM (global circulation model) scenarios. As highlighted below, researchers have also examined vulnerability in the wider gene pools of major crops, which include the potentially valuable wild species related to them.

Climate change poses a threat to livestock, aquaculture and fisheries as well. Since these are critical sources of food and income for rural people, CGIAR researchers have begun to look closely at changing conditions that make them more vulnerable.

Some CGIAR Centers are also examining the likely effects of climate change on major biotic stresses in agriculture, including certain human and animal diseases, like malaria and trypanosomiasis, which are transmitted by insects. These stresses already cause considerable direct damage to crops, animals, and people, and their depredations may increase as a result of changes in the global climate. Researchers are using simulation models with GIS to predict the severity of major crops diseases under changes in temperature and rainfall. Coupled with the CGIAR's large store of knowledge about disease epidemiology, these tools will be critical for anticipating the effects of climate change on the spread of dangerous pathogens worldwide.

Other studies are monitoring the vulnerability of specific natural resources and ecosystems. For example, significant efforts are under way in the CGIAR to anticipate climate-change related impacts on water supplies and to determine the consequences for forests, tropical peat lands and coral reefs. With respect to the latter, higher sea temperatures are expected to contribute to significant coral "bleaching," resulting in the destruction of vital fish-breeding habitats. CGIAR scientists are monitoring this phenomenon with the aid of a tool called ReefBase.

Finally, as highlighted below, CGIAR researchers in sub-Saharan Africa have mapped on a continental scale the vulnerability of entire agricultural systems to the double menace of climate change and poverty.

In all of this work, a key challenge is to expand the scope and increase the precision of the analysis. Another is to establish effective means of sharing more widely the information that policy-makers, local decision-makers, rural people, development organizations and others will need to anticipate and adapt to expected climate changes.

### ***Research highlight—Charting the demise of crop wild relatives***

CGIAR scientists used a simulation model to quantify the impact of climate change on the geographical distribution of wild species related to four important food crops: cowpea, peanut, potato and rice.

They estimated that 16 to 22 percent of the wild relatives of the first three crops will become extinct by 2055 and that the distribution of most of them will be reduced by more than half. The exact rate of extinction and habitat loss will depend on the pace at which wild species manage to migrate as rising temperatures contribute to making current habitats unsuitable.

Crop wild relatives are valuable, because they contain genes for traits such as drought tolerance and pest resistance, which could prove useful for adapting crops to harsher conditions. It is, therefore, urgent for the future of agriculture that samples of endangered wild species be collected and preserved in genebanks. In addition, the habitats of crop wild relatives must be protected so as to conserve, not just the plants themselves, but the evolutionary process through which genetic diversity continues to be created in the wild.

Information generated through this research can serve as a guide to both of those measures.

### ***Research highlight—Hotspots of vulnerability in Africa***

A recent study carried out by CGIAR scientists in sub-Saharan Africa used several climate models to examine four different scenarios for the region toward 2050. The most vulnerable areas are the West African Sahel; the rangelands, Great Lakes and coastal areas of Eastern Africa; and the drier zones of Southern Africa. Researchers characterized the vulnerability of those and other areas in terms of various biophysical and social factors (such as soil degradation, market access, infant mortality and HIV prevalence) and then integrated the results with those for climate change.

The combined results indicate which agricultural systems, by country, constitute “hotspots of vulnerability.” Published in 2006, these results have already been used in several influential studies, including the UK government’s *Stern Review on the Economics of Climate Change*. In addition, the research has highlighted important points for future vulnerability assessments. It is clear, for example, that since macro-level studies mask enormous variability at the local level, the analysis must ultimately be done on a national basis, preferably with rural communities playing a central role. CGIAR researchers and national partners have recently undertaken their first such analysis.

### **Adapting Agricultural Systems to Climate Change**

The performance of crops, wild plants, livestock and aquatic resources under stress depends both on their inherent genetic capacity and on the whole agroecosystems in which they are managed. Any serious effort to increase the resilience of developing country agriculture in the face of climate change must involve the adoption of climate-resilient crop varieties and animal breeds as well as more prudent management of crops, animals and the natural resources that sustain their production while providing other vital services for people and the environment.

### ***Crop research in progress***

New scientific tools are proving to be helpful in speeding the progress of crop improvement. Particularly important are techniques from molecular biology, which enable plant geneticists to identify and select for genes controlling stress tolerance with far greater efficiency. The CGIAR Centers are actively employing molecular marker-assisted selection to accelerate the improvement of crops for resistance to diseases and insects and tolerance to various biotic stresses, such as drought and flooding.

A key advantage of the Centers in this work is their ability to link research in molecular biology with large-scale conventional breeding programs that have a regional or global reach and encompass all of the world’s staple foods. These include the major cereals (maize, rice and wheat); other cereals that are important for particular regions and uses (barley, millet and sorghum); starchy roots and tubers (cassava, potato and sweetpotato);

grain legumes (chickpea, common bean, cowpea, faba bean, grasspea groundnut, lentil and pigeonpea); banana and plantain; and major forage grasses.

In genetic improvement of those crops, CGIAR researchers draw on the approximately 600,000 genetically diverse plant samples safeguarded *ex situ* in 11 genebanks, which the Centers operate under the terms of the International Treaty on Plant Genetic Resources for Food and Agriculture. The samples include traditional landraces resulting from farmer selection as well as wild species related to crops. The Centers have already made excellent use of these materials, but much remains to be done. For this purpose CGIAR researchers are devising new methods to characterize the *ex situ* collections more rapidly for adaptations that might be useful in breeding for stress tolerance.

As highlighted below, CGIAR researchers have been able to achieve dramatic progress in boosting the resilience of major staples – principally maize, rice and wheat. They are also building on the “evolutionary advantage” of naturally hardy food crops, such as barley, cassava, pearl millet, sorghum, and groundnut, which are widely grown in dry climates. A key challenge in this research is to identify the genetic mechanisms that account for the inherent stress tolerance of those crops and exploit them more thoroughly through plant breeding.

#### ***Research highlight—Drought-tolerant maize***

Drought reduces global maize yields by as much as 15 percent annually, representing crop losses of more than 20 million tons of grain. As part of a worldwide effort to curb these losses, CGIAR scientists are working with national partners in sub-Saharan Africa to develop drought-tolerant maize varieties. So far, more than 50 such varieties have resulted from this work, and they are being grown on a total of about one million hectares.

The success of this work is partly the result of a novel breeding method, in which hundreds of small farmers take part in testing new varieties under harsh growing conditions. In search of further yield gains, scientists are identifying areas of the maize genome that are linked to drought tolerance, with the aid of a molecular genetic map, based on data indicating the performance of different types of tropical maize in diverse environments.

#### ***Research highlight—Flood-tolerant rice***

In Southeast Asia alone, rice harvest losses related to flooding have an estimated annual value of US\$1 billion. Rice is the only cereal crop that can withstand any degree of submergence, but most varieties die if fully submerged for more than three days. Now, CGIAR researchers and collaborators have identified a rice gene called Sub1A, which allows plants to survive completely submerged for up to two weeks. The trait has been successfully transferred into a popular rice variety in Bangladesh, and the improved version is giving high yields while protecting harvests against flooding.

### ***Research in progress on cropping systems and natural resource management***

The breeding of climate-resilient varieties must go hand-in-hand with efforts to bolster the resilience of the diverse cropping systems employed by developing country farmers. For that reason, the CGIAR Centers engaged in crop improvement also devote significant effort to research on crop and soil management.

This work has given rise to a wide array of options, including crop rotations, various approaches to crop diversification, better management of crop residues and integrated crop-livestock systems. One increasingly important option is conservation agriculture – a practice that combines reduced or no-tillage with crop rotations and permanent soil cover. Another promising approach is precision agriculture, featuring the use of timely, accurate information to optimize agricultural production, particularly through more efficient management of purchased inputs and natural resources.

A key insight from CGIAR research on crop and soil management is that holistic and dynamic approaches are required to achieve lasting solutions to declining productivity and natural resource degradation in farming systems across the developing world. The Centers and their partners have developed and are actively promoting a wide variety of such approaches, involving, for example, the integration of multipurpose grain, tree and forage legumes into traditional farming systems, and better management of animal manures. Some of the technologies resulting from CGIAR research, in addition to helping farmers adapt to harsher growing conditions, contribute to lowering greenhouse gas emissions, for example, by reducing tillage, leaving crop residues in the soil and increasing fertilizer-use efficiency.

Increasingly, work on cropping systems and soils is integrated with research on water management. Since the early 1990s, the CGIAR has been engaged in a major effort to improve the productivity of water in agriculture. According to the just-completed *Comprehensive Assessment of Water Management in Agriculture*, more than a third of earth's population is already affected by water scarcity. Coordinated by CGIAR researchers, the Assessment was a 5-year study that brought together some 700 specialists to examine the impacts of water policies and practices prevailing over the last 50 years.

Climate change will put greater pressure on water resources, as increasingly volatile rainfall patterns force farmers to rely more heavily on irrigation. But, fortunately, the *Comprehensive Assessment* points to a wide range of technologies and policy measures that could increase water productivity in both irrigated and rainfed agricultural systems, including those that incorporate livestock and fisheries.

Much CGIAR research aimed at increasing water productivity centers on community-based approaches for improving watershed management and strengthening food security in principal river basins throughout the developing world. Researchers examining the use of water and land resources in the basins are assessing the vulnerability of the poor to extreme weather events and identifying strategies to help them cope with these. In

addition, they are engaged in projects for assessing and improving the management of wetlands, which provide important environmental services while also supporting human livelihoods.

CGIAR specialists in water management are paying particular attention to drought. Their overall aim is to replace conventional “reactive” approaches, which rely on relief, with more pro-active strategies, which use powerful information tools to guide actions in advance for mitigating drought impacts.

### ***Research highlight—Water harvesting in dry regions***

In addition to calling for more rational and efficient approaches to irrigation, the recently published *Comprehensive Assessment of Water Management in Agriculture* draws attention to the potential for better management of rainwater, even where it is very scarce. Farmers in West Asia and North Africa, for example, inhabiting some of the driest regions on earth, have traditionally practiced “water harvesting.” This involves diversion of scarce rainfall from large areas into small parcels containing crops and trees. CGIAR scientists are studying numerous traditional systems for water harvesting, with the aim of helping refine and disseminate them more widely. In Syria, for example, mechanized construction of traditional micro-catchment ridges, using a special plow, has permitted the expansion of water harvesting in degraded rangelands, which has improved the survival rate of shrubs and other plants on which livestock graze.

### **Mitigating Climate Change through Better Land Management**

Developing countries increasingly recognize the need and opportunities for helping mitigate climate change. Their commitment is highly important, since current levels of greenhouse gas emissions caused by agriculture, including its contribution to deforestation in developing countries, account for up to 35 percent of total global emissions.

In collaboration with many developing country partners, CGIAR researchers are investigating a number of promising options for reducing emissions through innovative approaches to the management of tropical lands. These can permit the removal of significant amounts of greenhouse gases from the atmosphere, thus mitigating future climate change.

The success of these efforts depends in part on the new and rapidly growing world trade in certified reduction of carbon emissions. Under the Clean Development Mechanism (CDM) established by the Kyoto Climate Change Protocol, countries that do not meet their agreed targets in emission reductions can buy the service from other countries. Numerous carbon funds have been established for this purpose, but so far they have traded mainly with sectors such as energy and transportation in just a few developing countries.

Some schemes have been set up that cater specifically to agricultural and forestry projects. But in order for these to be implemented with the participation of large numbers of smallholders, numerous technological, institutional and other barriers must be overcome. As highlighted below, CGIAR researchers are finding effective means to overcome some of these obstacles.

### ***Research in progress on deforestation reduction***

Since deforestation through burning accounts for at least 20 percent of global carbon emissions, measures to curb this complex phenomenon ought to be one of the principal strategies for reducing greenhouse gas emissions. Yet, the Kyoto Protocol skirts this issue almost entirely, and countries rich in tropical forests initially resisted calls to reduce deforestation as a means of lowering emissions.

In recent years, however, those countries have relaxed their opposition. So, the way is open for negotiating new international agreements under which forest-rich countries would have fiscal and other incentives to undertake schemes for “reduced emissions from deforestation and degradation” (REDD). The end of the Kyoto Protocol in 2012 offers a key opportunity to formulate such agreements, which are already under discussion.

A central overall objective of CGIAR forestry and agroforestry research is to help construct a post-2012 regime that will lead to real emission reductions in ways that are efficient, equitable and beneficial for affected communities in developing countries. At the invitation of the United Nations Framework Convention on Climate Change (UNFCCC), CGIAR scientists have already joined other intergovernmental organizations in offering valuable advice on how best to reduce emissions from deforestation under a future agreement.

The CGIAR’s contribution to this process draws from a large body of ongoing research on the underlying causes of deforestation. In addition, Center scientists are testing and developing methods for establishing REDD baselines and monitoring changes in forest carbon stocks. They are also analyzing various policies, institutional arrangements and incentive schemes for implementing REDD mechanisms. Their chief contribution will be to help ensure that efforts to reduce deforestation are based on the best available knowledge about forests and climate change at the national, regional and global scales.

### ***Research in progress on agroforestry, biofuels and other options***

Agroforestry systems offer another option for mitigating climate change, while also helping rural people adapt to its consequences. In addition to capturing carbon and helping maintain soil health through nitrogen fixation and use of cuttings as fertilizer and mulch, agroforestry species provide useful products, such as animal fodder, fruit, timber, fuel, medicines and resins.

A further land-use option that shows potential for reducing greenhouse gas emissions – but also involves complex tradeoffs – is the production of biofuels. This could offer the

additional advantage of helping developing countries cope with increased energy prices, while providing rural communities with new sources of income and employment. The promise of biofuels, however, must be tempered with caution about a number of potentially negative consequences. One of the principal concerns is that biofuels compete with food and feed uses of basic cereals, driving up prices. Another is that crop production for biofuels will greatly increase the already worrisome pressures that intensive agriculture has placed on natural resources.

CGIAR scientists have undertaken research aimed at helping determine how those and other factors could balance out. The results will be essential for determining the conditions (including technologies, markets, policies and institutional arrangements) under which biofuel production can mitigate climate change, while also benefiting the poor in ways that are environmentally sustainable. Some CGIAR Centers are examining those issues within the framework of research on specific crops and agroecosystems.

The various land-use options outlined above are perhaps the most obvious candidates for reducing greenhouse gas emissions. But agricultural research offers many other possibilities as well for capturing carbon from the atmosphere and for reducing emissions of other greenhouse gases, specifically methane and nitrous oxide. Two significant agricultural sources of methane emissions are irrigated rice production and livestock, while nitrous oxide results from the application of nitrogen fertilizer. As illustrated by one of the highlights below, the CGIAR is engaged in vigorous and innovative efforts to find ways of reducing emissions from those sources.

***Research highlight—Measuring greenhouse gas emissions***

Accurately measuring the reduction of greenhouse gas emissions in projects involving agroforestry and other improved land-use options is currently very difficult. To address this problem, CGIAR researchers have devised and are applying a new technique in Eastern Africa that assesses soil conditions, including carbon stocks, with a high degree of accuracy. Involving the use of satellite imagery and infrared spectroscopy, the technique is much cheaper than on-the-ground verification. Using this technology, a team of scientists in Kenya are providing government officials with environmental data from an area of 19,000 square kilometer for guiding a comprehensive effort to rehabilitate degraded agricultural land in the watersheds that feed Lake Victoria.

***Research highlight—Inhibiting nitrification***

In research on tropical forages, CGIAR scientists are studying a chemical released from the roots of an important grass species, which triggers a process referred to as “biological nitrification inhibition” (BNI). This process slows the conversion of ammonium – the form of nitrogen used in most fertilizers – first into nitrite and then into nitrate and nitrous oxide. The latter, in addition to being a powerful greenhouse gas, contributes to depletion of the stratospheric ozone layer, making humans more vulnerable to ultraviolet radiation. Nitrate is crucial for crop growth, but much of it finds its way into streams and groundwater, causing serious contamination.

If scientists succeed in isolating the genes responsible for BNI and can introduce it into other crops, the results could be truly revolutionary. Varieties that slow nitrification to a level that is still consistent with good crop growth would not only help reduce greenhouse gas emissions but also lower water pollution, while enhancing productivity through more efficient use of fertilizer.

### **Developing Appropriate Policies**

Farming communities in parts of the developing are beginning to adapt to consequences of climate change that are already evident. What remains to be seen, of course, is whether both adaptation and mitigation will proceed quickly enough to forestall major dislocations and greater human suffering in rural areas. A key prerequisite for speeding the pace of progress on both fronts consists of policies that are conducive to sustainable improvement in agricultural production and natural resource management. CGIAR researchers are exploring a number of avenues with other international institutions and with partners in developing countries to support the development of such policies.

### ***Research in progress***

CGIAR research on forestry is sharply focused on helping build a reliable knowledge base to inform ongoing international dialogue about a new regime for reducing emissions by curbing deforestation in developing countries. Similarly, much of the CGIAR's research on water management is aimed at facilitating the development of national and transboundary policies that foster more prudent use of an increasingly scarce natural resource in support of rural livelihoods, considering the likely effects of climate change. This policy research is also beginning to seek ways of lessening the potentially overwhelming shock that climate change could cause to fisheries and aquaculture, which provide the main source of animal protein for a billion people worldwide.

Those policy research initiatives are key components of a broader effort to shape policy development in the face of global climate change. It involves cutting-edge research, using flexible analytical tools and data platforms to characterize and quantify the main drivers of change and to assess their implications for food security and agricultural systems. A central aim of this work is to generate relevant and reliable information that provides policy makers, investment analysts and civil society representatives with a sound basis for taking decisions about difficult tradeoffs between conservation and development. CGIAR researchers have already supplied quantitative analysis of plausible outcomes in support of various ongoing international studies, such as the UN-supported Millennium Ecosystem Assessment.

Among the products that will come from CGIAR policy research are simulation models that permit comprehensive assessments of the many factors affecting food security, poverty and the environment, as influenced by climate change. Such information is critical for constructing plausible development scenarios that better enable policy makers

to define a vision of the way forward to sustainable development and design measures that will help realize that vision.

Without such measures, the Millenium Development Goals will most likely remain an empty promise for many of the world's rural poor, particularly as they face the menace of global climate change.

## **Annex: About the CGIAR**

The Consultative Group on International Agricultural Research (CGIAR), established in 1971, is a strategic partnership of countries, international and regional organizations and private foundations supporting the work of 15 international Centers. In collaboration with national agricultural research systems, civil society and the private sector, the CGIAR fosters sustainable agricultural growth through high-quality science aimed at benefiting the poor through stronger food security, better human nutrition and health, higher incomes and improved management of natural resources. [www.cgiar.org](http://www.cgiar.org)

### **CGIAR-Supported Centers**

The 15 Centers supported by the CGIAR are autonomous organizations, each with its own charter, board, director general and staff. Center scientists are recruited from around the world.

Africa Rice Center (WARDA)  
Cotonou, Benin  
[www.warda.org](http://www.warda.org)

Bioversity International  
Maccarese, Rome, Italy  
[www.bioversityinternational.org](http://www.bioversityinternational.org)

Internacional Center for Tropical Agriculture (CIAT)  
Cali, Colombia  
[www.ciat.cgiar.org](http://www.ciat.cgiar.org)

Center for International Forestry Research (CIFOR)  
Bogor, Indonesia  
[www.cifor.cgiar.org](http://www.cifor.cgiar.org)

International Maize and Wheat Improvement Center (CIMMYT)  
Texcoco, Mexico  
[www.cimmyt.org](http://www.cimmyt.org)

International Potato Center (CIP)  
Lima, Peru  
[www.cipotato.org](http://www.cipotato.org)

International Center for Agricultural Research in the Dry Areas (ICARDA)  
Aleppo, Syria  
[www.icarda.org](http://www.icarda.org)

International Crops Research Institute for the Semi-Arid Tropics (ICRISAT)  
Patancheru, Andhra Pradesh, India  
[www.icrisat.org](http://www.icrisat.org)

International Food Policy Research Institute (IFPRI)  
Washington, D.C., USA  
[www.ifpri.org](http://www.ifpri.org)

International Institute of Tropical Agriculture (IITA)  
Ibadan, Nigeria  
[www.iita.org](http://www.iita.org)

International Livestock Research Institute (ILRI)  
Nairobi, Kenya, and Addis Ababa, Ethiopia  
[www.cgiar.org/ilri](http://www.cgiar.org/ilri)

International Rice Research Institute (IRRI)  
Los Baños, Philippines  
[www.irri.org](http://www.irri.org)

International Water Management Institute (IWMI)  
Battaramulla, Sri Lanka  
[www.cgiar.org/iwmi](http://www.cgiar.org/iwmi)

World Agroforestry Centre (ICRAF)  
Nairobi, Kenya  
[www.worldagroforestrycentre.org](http://www.worldagroforestrycentre.org)

WorldFish Center  
Penang, Malaysia  
[www.worldfishcenter.org](http://www.worldfishcenter.org)