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Reducing Poverty through Cutting-edge Science

The CGIAR and Climate Change
Progress Report of the Inter-Center Working Group on Climate Change

Attached is a progress report of the Inter-Center Working Group on Climate Change for discussion under Agenda item 4(b), *Climate Change*.

THE CGIAR AND CLIMATE CHANGE
Progress Report of the Inter-Center Working Group on Climate Change to International Centers Week
26 October 1999

SUMMARY

The CGIAR Center Directors Committee (CDC) established the Inter-Center Working Group on Climate Change (ICWG-CC) at the 1998 Mid-term Meeting in Brasilia to evaluate the consequences of CGIAR- related activities on global climate change, and to develop a strategy to incorporate climate change into the CGIAR agreed agenda. USAID is funding the project designed to tackle these activities. Phase 1 of the project has been implemented based on 14 case studies prepared by 12 CGIAR centers.

The projected effects of climate change on developing country crops, livestock, forestry and fisheries are likely to be of enormous significance to food security, poverty reduction and protection of the natural resource base in the next decades. As an institution dealing with strategic research issues, the ICWG-CC considers that the CGIAR has no option but to include the drivers of climate change into its agreed agenda. A CGIAR-wide strategy is being developed, based on the collaborative advantage of the CGIAR as seen by the larger global change research community. Considering the CGIAR's comparative advantage in relation to alternative sources of supply, the ICWG-CC concluded that the CGIAR priorities should be a shared responsibility in adaptation research and the lead responsibility on mitigation research in developing countries, both done in collaboration with the International Geosphere-Biosphere Program (IGBP), particularly its core programme GCTE (Global Change in Terrestrial Ecosystems).

Three priority areas on adaptation research were identified:

- Integrated gene management to cope with expected changed climates
- Protection of *in-situ* biodiversity with changed climates
- Development of tools to cope with less and more erratic water resources

Three priority research areas were identified for mitigation research:

- Increasing carbon stocks in agroecosystems
- Improving nitrogen use efficiency with less nitrous oxide emissions
- Improving water use efficiency

Details on implementation and partnerships are in the process of being developed. It is recognized that more input is needed on issues related to policy, training, forests, and aquatic environments. Feedback from the CDC and the Group at ICW-99 will be incorporated into this work, and synthesized at a proposed joint TAC-ICWG-CC meeting in early 2000. The report will be submitted to TAC 78 in March 2000 and a final one to the CGIAR at MTM-2000.

INTRODUCTION

The Inter-Center Working Group on Climate Change was established by the Center Directors Committee at the 1998 Mid-term Meeting in response to presentations by two Co-sponsors on the need for the CGIAR to come to grips with climate change issues. The ICWG-CC is composed of representatives from the 16 Centers plus TSBF (Tropical Soil Biology and Fertility Program) and GCTE.

The objectives of the working group are to 1) evaluate the consequences of CGIAR- related activities in international agriculture research on global climate change, and 2) to develop a strategy to incorporate climate change into the CGIAR agreed agenda. The US Agency for International Development (USAID) is funding both activities.

A task force of the ICWG-CC met in Nairobi, Kenya 20-22 April 1999 to determine the methodology and approaches for the consequences study. They were shared with the Center representatives and followed up through e-mail dialogue. The working group held a workshop at Reading, UK, 24-25 September to consolidate the first phase of the project and determine the action steps for completion of the second phase. This report outlines the progress to date and is presented to the CDC and the CGIAR members. The outcome of these consultations will be used to develop a final document that will be presented to TAC in March 1999 and to the CGIAR at Mid-term Meeting 2000 in Dresden, Germany.

THE READING WORKSHOP

The workshop was held in conjunction with the GCTE Focus 3 Conference “Food and Forestry: Global Change and Global Challenges” which allowed ICWG-CC members to interact with the larger global change research community at a major international gathering. The ICWG-CC presented 12 posters at the conference and the Chair of the ICWG-CC gave the closing keynote address linking global climate change with food security and poverty reduction in the tropics. The presentations are collated in a publication to be available at International Centers Week 1999.

A total of 20 individuals participated in the Workshop. This included 12 representatives from 10 CGIAR centers, three investor agencies and five advanced research institutions. The working group members were: Pedro Sanchez (Chair), Peter Grace (Task Force Leader—CIMMYT), Richard Thomas (CIAT), Walter Bowen (CIP), Judith Thompson (IPGRI), Richard Tutwiler (ICARDA), Meine van Noordwijk (ICRAF), Dyno Keatinge (IITA), Reiner Wassmann (IRRI), Geoff Kite (IWMI), Markus Wolpereis (WARDA), Cheryl Palm (TSBF), John Ingram (GCTE), and Fiona Chandler (secretary). Other center participants were Myles Fisher (CIAT) and John Dodds (ICARDA). The CGIAR member representatives were Bill Sugrue (USAID), Uttam Dabholkar (UNEP) and John Lynam (Rockefeller Foundation). Observers from potential collaborating advanced research institutions included Peter Gregory (Reading University), Jan Verhagen (AB-DLO, Wageningen) and Daniel Murdiyarso (Impact Centre, Bogor Agricultural University).

PHASE I – IMPACT OF INTERNATIONAL AGRICULTURAL RESEARCH ON GLOBAL CLIMATE CHANGE

Phase I of the USAID-funded project is a quantitative assessment of CGIAR-related activities on global climate change over the period 1965-1995. Specifically the study addresses the impact of genetic and agronomic improvements that have been developed, adapted and/or promoted by the CGIAR and its partners, regardless of the place of origin of the technology or institutional attribution.

The study seeks to estimate changes in soil and aboveground carbon stocks and greenhouse gas fluxes for different transition scenarios per unit area. A transition scenario is defined as a change in ecological state (e.g. from natural grassland to high-input crop agriculture). An attempt is also being made to spatially extrapolate these values within CGIAR-mandated eco-regions and place them into the context of global changes in carbon storage and greenhouse gas emissions as estimated by the Inter-governmental Panel on Climate Change (IPCC). The latter is a difficult task, and not an essential element of the study, considering that the aerial extent of land use change over time is difficult to capture with the historical records that exist within the CGIAR Centers. The use of remotely sensed information would provide base data for such an extrapolation, but its acquisition and use is considered beyond the resources of this project.

The study only deals with issues that are significant in the context of global sinks and sources from agriculture (i.e. it will ignore small-scale, isolated issues if globally irrelevant even if locally important). The study is limited to CO_2 (more specifically, changes in terrestrial C stocks), CH_4 and N_2O fluxes only, although it is recognized other factors contribute to climate forcing e.g. aerosols, change in surface albedo, etc.

The basis for this assessment is a compendium of case studies (see table below) provided by the CGIAR Centers. The case studies provide information on a range of impacts, adaptation and possible mitigation strategies for climate change throughout the CGIAR and its partners. Quantitative data from the case studies relevant to the 1965-1995 historical impact assessment has been collected in a standardized spreadsheet format to facilitate its analysis. To complete Phase I, actual estimates of changes in terrestrial C stocks, greenhouse gas emissions for agricultural systems will be calculated using either validation data collected by Centers (if available) or algorithms based on the wider literature. For some terrestrial systems, quantitative estimates of C or gas flux, as a function of management-induced changes in ecological state, can be derived using empirical simulation procedures if relevant environmental data is available.

Estimates of C savings by the deflection of deforestation will be included. This is the result of decreasing the need to clear new land for agriculture, because of higher crop yields in existing agricultural lands. Case studies, which provide adaptation or mitigation strategies and lie outside of the assessment timeframe, potential impact assessments will be developed on post-1995 impact.

Center	Title of Case Study
CIAT	*The Effects of Different Land Use Options for the Latin American Savannas on Soil Carbon, Greenhouse Gas Emissions and Soil Fertility
CIAT	*Case Study on Land Use Changes in the Central Lowlands of Tropical South America
CIMMYT	*Bed-Planting Systems for Sustained Yield and Reduced Greenhouse Gas Emissions
CIP	*Expansion of Potato Production in Asia and its Likely Impact on Nitrous Oxide Emissions
ICARDA	*Uzbek steppe could help fight global warming
ICARDA	Barley-Legume-Grazing System in Dry Areas: Long-term Nitrogen and Carbon Effects
ICRAF	*Soil Fertility Replenishment in Eastern/Southern Africa and Changes in Carbon Stocks
IITA	*Modeling Soil Organic Carbon Changes Under Intensified Land Use in Tropical Conditions
ILRI	Introduction of Improved Fodder Rotations into Annual Cropping Systems in West Africa.
ILRI	Improvement in Animal Production: Control of the Livestock Disease Trypanosomosis, in Southwestern Ethiopia.
IPGRI	*Genetic Resources: Foundation of Biological Diversity and Buffer for Environmental Changes
IRRI	*Methane Emissions Affected by Changes in Land Use and Crop management in Rice Production: Case Studies
IWMI	*Food Production and Environmental Change at Basin and Field Scales
TSBF & ICRAF	*Land Use Options at the Humid Forest Margins: The Potential for Carbon Sequestration
WARDA	*Rice-Based Systems and Climate Change in West Africa.

**poster or paper presented at GCTE Conference at Reading, September 1999*

Phase I also includes a detailed assessment of the impact of the Green Revolution in Asia, specifically plant variety improvement, shifts in fertilizer usage and land use change on C stocks and GHG emissions. Details of the impact of land use changes in the vast tropical lowlands of South America, Southeast Asia and Africa are also included. These represent the last remaining large areas of the world where conversion to agriculture is likely to occur. Chronological shifts in variety, fertilizer- and land-use are reasonably well documented for regions and data has been obtained from IFDC, FAO and the Oak Ridge National Laboratory. A first draft of the Green Revolution assessment will be presented at ICW-99 as well as selected impact scenarios and mitigation strategies in relation to sustaining crop production and reducing greenhouse gas emissions.

PHASE II- STRATEGIC FRAMEWORK

A CGIAR-wide strategy on climate change was extensively discussed at the Reading workshop. The main items discussed included positioning the CGIAR in relation to the global climate change community, terminology, the role of the CGIAR, research priorities, partnerships, coordination options and next steps.

Current Institutional Set-up

Two major programmes (IGBP and IPCC) constitute the scientific input into the United Nations Framework Convention on Climate Change (UN/FCCC).

IGBP operates under the aegis of ICSU (International Council of Scientific Unions. IGBP is a hierarchical research programme with more than 1000 participating scientists – mainly biophysical, mainly from the North – who produce high quality science with an aggregate budget of $1 billion/year. IGBP is composed of several core projects such as GCTE (Global Change in Terrestrial Ecosystems), LUCC (Land Use and Cover Change), and works with IHDP (International Human Dimensions Program) and others in climate change. Several CGIAR scientists are leaders in IGBP activities; for example Peter Grace (CIMMYT) on tropical cereals modeling, and Meine van Noordwijk (ICRAF) on complex agroecosystems, work with GCTE and Robin Reid (ILRI) with LUCC. IGBP' executive secretary is Will Steffen, based in Stockholm. Ian Noble of the Australian National University chairs GCTE.

IGBP is developing a strategy for the next decade and in it the CGIAR is highlighted as a one of its major collaborators. The collaborative advantage of the CGIAR in IGBP's view is having:

- Scientists based in the developing world
- Expertise in human-dominated ecosystems
- Multidisciplinary character of the CGIAR
- Working from forests to marine ecosystems
- Access to relevant research sites throughout the developing world
- Access to NARS
- Access to policymakers in the South

IPCC is a formal arm of the UN/FCCC and is set up to provide scientific assessment to policymakers. Robert Watson, Director for the Environment at the World Bank, chairs the IPCC. IPCC is well known for its assessments, which are expressed as policy alternatives to the "parties" (countries) of the climate change convention, including the Kyoto Protocol. IPCC is now in the process of completing a special report on Land Use Change and Forestry, which sets up the policy options for implementing the Kyoto Protocol. The CGIAR is meaningfully involved in this exercise. Pedro Sanchez (ICRAF) and Reidar Persson (CIFOR) are among the lead authors involved in the preparation of this report, which will be finalized by May 2000. ICRAF Board member Daniel Murdiyarso is also a lead author and former IITA Board member John Stewart is a senior adviser.

Global change or climate change?

The IGBP definition of "global change" is far broader than climate change alone, important though this aspect is. Since inception, IGBP has included changes in atmospheric composition and land use within its definition of global change, but it has recently broaden this to also encompass other drivers such as climate variation, land use intensification and extensification, a changed global nitrogen cycle and water scarcity. These multiple changes, working both independently and interactively are primarily driven by the rapidly changing needs of a growing population, and have major consequences for poverty, food insecurity, urbanization, globalization of trade, information technology, resource degradation, pollution, species extinction, etc. While the CGIAR is tackling several of these consequences, the ICWG-CC, as its name indicates, focuses on the relationship between climate change, poverty and food security.

But climate change is more than global warming caused by increased levels of carbon dioxide (CO_2), methane (CH_4) and nitrous oxides (N_2O) in the atmosphere. Several "drivers" of global change are recognized to arise out of climate change. Current predictions of some of these major drivers, although less cataclysmic than before, include:

- a steady increase in global mean surface temperatures of 1 - 3.5 ^{0}C by 2100
- an accompanying increase in atmospheric CO_2 levels from the current 360 ppm to 400 – 750 ppm by 2100
- more frequent and severe extreme weather events (with us now)
- a shift in some places towards drier climates (parts of Africa) or more humid climates (the Andes)
- a sea level rise of 15 - 95 cm by 2100

"Shifts in climate" is perhaps a more apt term than climate change, as in many instances there may be no new climates per se, but changing climates in the same locations. In other instances, however, genuinely new climates may manifest, being a combination of changed mean temperature and rainfall, with different distribution throughout the year and changed seasonal and annual variability. The overall effects of climate change on agriculture and natural ecosystems are expected to be more negative in the tropics than in the temperate regions.

A Strategic Imperative

The effects of changes in climate and climate variability in developing country agriculture will be of enormous significance to food security, poverty reduction and protection of the natural resource base in the next decades. **As an institution dealing with strategic research issues, the ICWG-CC considers that the CGIAR has no option but to include climate change research into its agreed agenda.**

The wealth of information presented at the ICWG-CC workshop by Center participants clearly demonstrates the comparative advantage the CGIAR has in developing feasible strategies to adapt to, or mitigate climate change and sustain food production and reduce natural resource degradation. The management strategies proposed by all Centers have impact of a global significance. Assessment tools developed within the CGIAR Centers (for example simulation models developed by IRRI for estimating CH_4 emissions in rice) also provide quantitative means for scenarios-based assessments of management options, which have a global impact on greenhouse gas emissions and crop production. These tools need to be refined and their robustness evaluated across environmental space; while detailed "predictions" of future climates for given regions of the world are still some way off, analyses using simulation models can proceed based on a range of likely climate and management scenarios.

Types of Research

Climate change activities are usually placed in three categories: impacts, adaptation and mitigation. What these terms mean and some of the CGIAR current involvement is described below.

Impacts are the consequences of shifts in climate on something else (agriculture, fisheries, industry, health, etc). Impacts research focuses on **what will happen**. For example the effects of predicted decreased rainfall on crop yields at specific location. In the CGIAR we use the term impact in the context of the impacts of our research on food security, etc. To avoid confusion it is important to recognize this difference.

An excellent example of impacts research is the IWMI study on the effects of different climate change scenarios on the hydrology of the Gediz river basin in Turkey. On another front ICARDA is investigating the effects of altered nitrogen and carbon dynamics on integrated crop-livestock systems in dry areas subject to increasing drought and heat stresses. CIP described potential major consequences of the ongoing shift in potato production towards higher elevations in the Andes due to higher temperatures. It may result in massive CO_2 emissions when high organic matter soils of the páramos are turned over, as well as a destabilization of watershed functions critical to the inter-Andean valleys.

Work by CIMMYT, CIP and others show that 8 – 16% of the nitrogen applied as fertilizer goes off to the atmosphere as N_2O. N_2O is the most powerful greenhouse gas, with 310 times the global warming power of CO_2 because of its very long residence time in the atmosphere. This may be the main negative consequence of the Green Revolution on climate change.

Adaptation are actions to adjust to the consequences of climate change (**how to cope with what will happen**), for example more robust breeding strategies for increased climatic variability. The degree of adaptation required will depend on the resilience of the particular production system. For example altering the cropping system components to better use scarce water resources may be a more appropriate strategy than a breeding program. Furthermore agro-ecologies may be adapted to the effects of climate change through changes in land use, cropping patterns and livestock production systems.

Mitigation are actions to prevent further escalation of greenhouse gas emissions (**how to decrease global warming**). Mitigation is proactive rather than reactive and is aimed at preventing further escalation. Several examples of mitigation research in the CGIAR have been highlighted by the ICWG-CC:

- Increases in carbon sequestration in the soil or vegetation as a consequence of improved productivity. These include improved pastures in the South American savannas (CIAT), soil fertility replenishment in Eastern/Southern Africa (ICRAF), agroforestry alternatives to slash and burn in the humid tropics (TSBF-ICRAF), and agroforestry in the moist savannas of West Africa (IITA). A major soil C sequestration potential exists through the rehabilitation of 350 million hectares of degraded grassland in Central Asia as indicated by ICARDA.

- Decreasing methane emissions. These include breeding and improved water management practices in irrigated paddy rice soils (IRRI), preventing net CH_4 emissions to the atmosphere from paddy rice and cattle grazing by adjacent agroforests acting as methane sinks at the landscape scale (ICRAF), and reducing methane emissions from livestock with improved diets (ILRI). The IRRI study was the most comprehensive, based on three contrasting case studies in Asia, which provide a range in methane fluxes from decreases of 40 – 70% to increases of 10 to 800%.

- Decreasing N_2O emissions. Ways of mitigate those emissions caused by nitrogen fertilization include delaying the timing of N applications to wheat in Mexico and introduction of a bed planting system to wheat in India (CIMMYT). At the margins of the humid tropics, best-bet alternatives to slash and burn agriculture did not reduce N_2O emissions except in relation to high-input cropping (TSBF-ICRAF).

Priority Setting

The ICWG-CC concluded, after intensive discussions, that the CGIAR's comparative advantage in relation to IGBP-GCTE as an alternative source of supply was in adaptation and mitigation research.

Type of research	CGIAR	IGBP-GCTE
Impacts (consequences)	Very little	Lead responsibility globally
Adaptation research	Shared responsibility in developing countries	Lead responsibility in developed countries
Mitigation research	Lead responsibility in developing countries	Lead responsibility in developed countries

There was broad consensus in this prioritization. Two centers, however, while in general agreement with the consensus, expressed additional views. IWMI believes that they can carry out impact studies on water resources and, in particular, impacts on irrigated agriculture and food production, while IITA felt that the need to restore nutrient-depleted and weed-infested lands in the moist savannas is so urgent that climate change research is a lesser priority. Other centers felt comfortable with the priority for adaptation and mitigation research because they directly address

CGIAR goals in a strategic manner, with climate change mitigation being a by-product of increasing food security, eliminating poverty and protecting the environment.

STRATEGIC ELEMENTS

The ICWG-CC identified six priority research areas, three in adaptation research and three in mitigation as follows:

Adaptation Research

Integrated gene management to cope with expected changed climates. Centers need to develop practical ways to use genetic x environment interactions to predict how various CGIAR germplasm accessions (crops, pastures, livestock, trees and fish) would respond to shifts in climate and increasing climatic variability at key locations. Such geo-referenced information would help NARS and other partners to plan ahead and tackle these expected shifts in rainfall variability, higher temperatures, new or more important pests and diseases, and higher atmospheric CO_2 levels. Each CG center responsible for plant or animal germplasm, should set up a catalogue of genetic x environment interactions. The fledgling ICIS (International Crop Information System) project being led by CIMMYT and IRRI provides such information in a relational database, and could play a critical role in identifying germplasm for maximum yield for environments worldwide.

CGIAR centers should coordinate their efforts in the development and standardization of crop growth simulation models to do scenario planning. Many Centers provide GIS facilities, which allow these simulation models to be used in dynamic genetic x environment x management pre-testing, including the use of conservation tillage practices to enhance carbon sequestration in soils. Analysis of the consequences (impacts) of climate change can be done primarily by ARO's in collaboration with CGIAR center scientists.

Selection and breeding programs may need to be reviewed to assure there is a match between productivity goals and expected new abiotic stresses as well as new biotic ones. Molecular biology approaches may serve a useful function. The overall goal is increased resilience of our germplasm to counteract current vulnerabilities to climate change.

Protection of in-situ biodiversity with changed climates. The natural habitats of some plant species may "migrate" in response to changed climates, but for many species relevant to center mandates, including the ones of concern by IPGRI, migration rates may be too slow to save stocks of *in-situ* biodiversity. A specific project, perhaps under the leadership of the SGRP—Systemwide Program on Genetic Resources should be developed to assure that the centers of diversity relevant to the CGIAR are not wiped out by climate change in the next decades. This would expand and complement ICARDA and IPGRI 's GEF project with four NARS on *in situ* agrobiodiveristy conservation in threatened ecosystems in the Near East region

Coping with sea level rise will affect marine and coastal ecosystems including coral reefs, coastal fisheries, mangrove systems and salt-water intrusion. This subject needs further elaboration and particular input from ICLARM.

Develop tools to cope with less and more erratic water resources. Developing countries are expected to experience major reduction in the availability of fresh water in the next decades. Currently 7% of the world's population (mainly in WANA and Southern Africa) are at stress levels of water availability (<2000 m^3/capita/year). By 2050, 70% of the world's population will be at such stress levels. Although this shortfall is not necessarily triggered by climate change, it is likely to be exacerbated in regions of the developing world that are predicted to have drier climates. ICARDA has substantial programs on improving on-farm water use efficiency and the utilization of marginal water resources to address issues of declining water quantity and quality in the Dry Areas. IWMI should lead a system wide strategy on how to cope with this emerging constraint perhaps building the global climate change element more explicitly into the SWIM systemwide program.

Mitigation Research

Increasing carbon stocks in productive systems. About 20% of the carbon emissions to the atmosphere as CO_2 come from tropical deforestation and land use, as well as 50% of the anthropogenic CH_4 emissions. Projections indicate that the share of agriculture and forestry in CO_2 emissions will increase in the next decades. Given the investments of the CGIAR centers in most agricultural as well as natural ecosystems--from the forests to the desert margins---the CGIAR is uniquely positioned to play a major role in climate change mitigation. Carbon stocks are also now being traded on the world market, mainly through countries in the North finding relatively inexpensive investment strategies for carbon storage in he tropics, where storage potential is high. This can have major spin-offs in terms of food production.

Terrestrial tropical ecosystems are one of the largest reservoirs of the world's carbon stock, and some could become either net sources or net sinks of carbon depending on how they are managed. Practices that provide benefits to farmers in terms of increasing productivity and income are often compatible with increased carbon sequestration and biodiversification in terrestrial farming systems e.g. conservation tillage and rotations with grain legumes. Examples already developed by the CGIAR include replenishing the fertility of degraded soils through biological means, shifting from crops to trees that produce high-value products, shifting from degraded pastures to agroforests in the humid tropics, and the use of improved pastures with deep-rooted grasses in the savannas.

In addition some labor-intensive improved technologies at the margins of the tropical forests may save large amounts of carbon sequestered by the forests from deforestation as well as its biodiversity. The same concept applies to other natural ecosystems in sub-humid, semi-arid and Mediterranean climates that harbor valuable biodiversity. Others carbon-conserving practices may be yield-neutral, for example decreasing methane emissions in paddy rice.

Methane emissions from paddy soils can be significantly reduced by a combination of genetic improvement and management practices such as drainage as highlighted in an IRRI research project funded by the GEF, which is reaching its completion stage. Methane emissions from ruminant livestock can also be managed and reduced with improved feeding. Agroforests and other tree-based systems serve as methane sinks in landscapes that include paddy rice and degraded pastures. A CGIAR-wide specific project on methane mitigation should be considered.

Improving nitrogen use efficiency with less nitrous oxide emissions. The global nitrogen cycle is being changed as a result of global change drivers beyond climate change *per se*. More nitrogen is now fixed from the atmosphere by human activities (140 Tg N/y) than by natural biological processes (BNF) (100 Tg N/y). The CO_2 fertilization effect (higher plant production in response to elevated CO_2 in the atmosphere) requires a corresponding increase in nitrogen and other nutrients in order for it to occur at an agronomically relevant scale. Current indications are that increasing atmospheric CO_2 levels by 50% (a plausible scenario during the 21st century) would increase cereal yields only by 8% if nitrogen is limited and by 15% if nitrogen is not limiting.

The efficiency of nitrogen fertilizer use in improved cropping systems in developing countries is low (10 – 30%); in the process 8 –16% of the fertilizer N is emitted to the atmosphere as N_20. This has significant consequences in global warming since one molecule of N_20 has over the 200 times the global warming potential of one molecule of CO_2. About 70% of the anthropogenic N_20 emissions come from agriculture. One of the clear consequences of the green revolution is major increases in N_20 emissions to the atmosphere. Improving nitrogen use efficiency in developing countries would not only have poverty reduction potential but also positive environmental feedbacks. Three complementary approaches can be considered for a system-wide effort.

<u>Improving N fertilizer use efficiency</u>. Recent CIMMYT work has shown sound agronomic ways to decrease N_20 emissions. Less recent work by nearly all the commodity-focused centres, IFDC and some NARS have shown ways to improve N fertilization efficiency, but without measuring N_20 emissions. Quantifying the current best practices of efficient fertilizer nitrogen use by farmers in terms of N_20 emissions would be the first step in a multi-center project. This is all the more critical in the high-potential growth countries of South Asia where nitrogen fertilizer use increased by 11% in 1997, as opposed to a global decline in usage during the same time.

<u>Maximize biological N fixation in crop systems with a legume component</u>. Major strides have been made by IITA and CIMMYT with mucuna fallows in West Africa and Central America, which provide 50 –100 kg N/ha to the following crop, as well as by ICRAF with leguminous tree fallows in Eastern/Southern Africa that provide 100 – 200 kg N/ha to subsequent crops. CIAT has demonstrated the beneficial effects of forage legumes for increased production, carbon accumulation and soil improvement in agropastoral systems. In these cases, the amounts of nitrogen added to the soil are as large as recommended N fertilizer applications, while avoiding the CO_2 cost of manufacturing and transporting fertilizers. Although it is often assumed that the efficiency of biologically-fixed N is equal or superior to that of fertilizer N, there is no hard data comparing N_2O emissions from these two types of N sources at the plot, let alone landscape scale. This is another opportunity for strategic CGIAR research that has the potential to increase incomes as well as mitigate global warming.

<u>Increasing the efficiency of N use by crops</u>. This is done through genetic manipulation and breeding. Since phosphorus deficiency frequently overwhelms both BNF and N utilization efficiency, selecting and breeding crops for P use efficiency would also be a component of this area of research in phosphorus-limited systems. Some of this work is being done by CGIAR centers and others, but at a scale clearly insufficient to have global impact.

Improving water use efficiency. Currently crops utilize (via transpiration) only about 15% of the available water in irrigated systems, and 22% in rainfed systems. The efficiency in of water use in marginal areas like the Sahel may be as low as 6%, meaning that 94% of the available and erratic rainfall there is lost to the farming system. Improving the efficiency of water use through management practices would make a major difference in dealing with expected water shortages. Two well-known approaches to increase water use efficiency are 1) put more of the water resource into transpiration and 2) use plants to fix more carbon per unit of water transpired.

Putting more water through transpiration can be done by cutting down on the 30% loss in the storage and delivery of water to fields in irrigated systems, and by reducing surface runoff with soil conservation structures, breaking the soil crust in the Sahel, or by agroforestry which has been shown to double transpiration rates. Increased transpiration efficiency can be done by genetic improvement or by manipulating microclimates in ways that increases the humidity of the air. Strengthening the current SWIM systemwide programme, particularly in areas predicted to have a drier climate in the next decades should be considered.

IMPLEMENTATION

Although this strategy is at an early stage of development the ICWG-CC has discussed some implementation options. The ICWG-CC unanimously rejected the idea of a new systemwide programme on the grounds that this work should be an integral part of each center's agreed agenda rather than something peripheral. An issue so central to the CGIAR mission should not be seen as an added activity. This is similar to when the CGIAR decided to strengthen social sciences and implemented this without any creating a systemwide program.

More input is needed on issues related to policy, training, forests and aquatic environments.

The ICWG-CC sees a need to facilitate the preparation of joint proposals and insure common methodologies, monitoring progress as well as nurturing the incipient partnership with IGBP/GCTE. Options for technical coordination and yearly meetings will be explored.

Partnerships with advanced research organizations should be developed. Several groups have already expressed interest in joint research projects. The ones wishing to be involved so far are as follows:

- Wageningen Centre of Climate Change Research, Netherlands. Siebe van der Gijn, Jan Verhagen (Email: a.verhagen@ab.dlo.nl).
- ISRIC, Netherlands. Niels Batjes (Email: Batjes@ISRIC.NL)
- Institute of Terrestrial Ecology, Scotland. Melvin Cannell. (Email: bush@ite.ac.uk).
- University of Florida. Jim Jones (Email: jwj@water.agen.ufl.edu).
- University of Reading, UK. Peter Gregory. (Email: P.J.Gregory@reading.ac.uk).
- Bogor Impacts Centre, Indonesia. Daniel Murdiyarso (Email: d.murdiyarso@biotrop.or.id).
- FAO. Louise Fresco. (Email: louise.fresco@fao.org).

Other institutions and individuals are most welcome to express their interest.

NEXT STEPS

Finalization of Phase I by December 99
Consultation with CDC and presentation to plenary at ICW-99
Joint TAC-ICWG-CC in early 2000
Finalization of the strategy
Report to TAC March 00
Report to CGIAR Mid-term Meeting, Dresden, May 00
Work really begins

ICWG-CC MEMBERS

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