



The Consultative Group on International Agricultural Research

The CGIAR is a strategic partnership, whose 64 members support 15 international research Centers working in collaboration with hundreds of government and civil society organizations as well as private businesses around the world. CGIAR members include 21 developing and 26 industrialized countries, four co-sponsors and 13 other international organizations.

Research supported by the CGIAR is aimed at fostering sustainable agricultural growth that benefits the poor through strengthened food security, enhanced human nutrition and health, higher incomes and improved management of natural resources. The knowledge and other products resulting from this collaborative research are made widely available to individuals and organizations working around the world for sustainable agricultural development.

Early Research and Accomplishments

Established in 1971, the CGIAR initially focused its support on efforts begun in the 1960s to combat hunger through improvement of major cereals – maize, rice and wheat – in developing countries. The continuous stream of improved varieties resulting from those efforts, together with changes in crop management, have made possible a steady rise in crop productivity over the past 40 years, commonly referred to as the “Green Revolution.” Further research initiated during the 1970s was aimed at improving many other staple crops and at dealing with the constraints of marginal production environments, including the semi-arid tropics and drier areas.

In addition to generating a wide array of improved germplasm and other useful products, the CGIAR Centers accomplished two other important tasks for agricultural development.

- Systematically collect and conserve ex situ traditional landraces, crop wild relatives and other genetic materials. The genebanks established by the Centers represent the world’s most important international effort to conserve plant genetic resources, safeguard more than 600,000 samples of crop, forage, and agroforestry species. The Centers hold these materials in trust for humanity.
- Enhance the capacity of national organizations across the developing world through training (provided to about 75,000 scientists) and collaborative research.

Reducing the “Ecological Footprint” of Agricultural Growth

By the 1980s, it was evident that rapid growth in agricultural productivity, while needed to meet growing demand for food, was being achieved at the cost of substantial damage to natural resources. The CGIAR committed itself to helping achieve sustainable agricultural development and took a number of steps toward this end. In the early 1990s, the crop-oriented Centers broadened their research agendas to place even more emphasis on natural resource management, and a series of programs was created with

the aim of coordinating this work across Centers. In addition, the CGIAR extended its support to four additional Centers focusing exclusively on natural resource management.

These initiatives have proved to be powerful instruments for starting to reduce the “ecological footprint” of agricultural intensification, through more effective and sustainable management of soil fertility, water, forests, agroforestry species and fisheries.

Confronting Global Challenges

To further sharpen its focus on the challenges of sustainable agriculture, the CGIAR has embarked in recent years on a reform process. Specifically, it aims to strengthen the scientific foundation of the CGIAR’s work, broaden its partnerships and streamline its operations.

A key task of the reform process was to review and revise the CGIAR’s research priorities, which are now defined as follows:

- Sustaining biodiversity
- Producing more and better food at lower costs through genetic improvement
- Reducing rural poverty through agricultural diversification and emerging opportunities for high-value products
- Promoting poverty alleviation and sustainable management of water, land and forest resources
- Improving policies and facilitating institutional innovation

Another central pillar of the reform process consists of “Challenge Programs.” Four have been established so far, aimed at combating micronutrient malnutrition, overcoming water scarcity, harnessing the power of molecular biology for agricultural development and fulfilling the promise of sustainable agriculture in sub-Saharan Africa. A second “cycle” of Challenge Programs is now under development.

In the spirit of reform, the Centers have designed a new framework for collective action, the Alliance of the CGIAR Centers. It is a formal coalition that coordinates resources and programs as a means of optimizing collective action on issues and in geographic areas where concerted efforts can significantly increase impact in solving critical problems.

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CGIAR Centres Update: Climate Change Activities

***For joint CGIAR-Global Environmental Change
scientific workshop on
“Climate Change, Agriculture and Food Security”***

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Foreword

Even though considerable uncertainty remains regarding the likely impacts of climate change on agriculture—the most climate-sensitive sector of all—there is by now general agreement that climate change will bring about large adverse impacts on rural developing economies and is a major threat to future food security, even though specific impacts are highly uncertain, trends are nonlinear, and surprises are more likely than not.

All CG Centres have recognised the importance of climate change and have incorporated into their research priorities and programs research activities on climate change impact analysis, mitigation options, or adaptation strategies; and several Centres have recently established dedicated programs in this research area. The Inter-Centre Working Group on Climate Change is another indicator of the importance accorded by the CG to research in this area.

The information provided by the Centres describes a rich picture of current research strengths and comparative advantage, particularly in the areas of breeding for climate change of individual crops, agronomic modelling; and farm-management practices with a focus on the poorest of the poor. Carbon sequestration activities are another area where some CG Centres have a comparative advantage. All CG Centres have published in the area of climate change research (see separate bibliography).

Interestingly, while some Centres focus their activities on one or a few climate change research areas, others have ongoing activities in many research areas (see also Tables 1 and 2). Of note, several research activities are carried out by several Centres, providing an opportunity for collaboration to optimally use scarce resources [e.g. downscaling of GCM data, which is carried out in several Centres].

The description of ongoing CG Centre research on climate change presents several entry points for mutual benefit of collaboration with the wider Global Change community. Some of the research gaps are enclosed in the companion document. Others will need to be identified through more detailed assessment.

Table 1. Climate Change — Summary of CG Centre Research

CG Centre Research	CG Centres involved
General focus	
- Research on Impact	BIOVERSITY, CIFOR, CIMMYT, ICARDA, IFPRI, ILRI, IRRI,
- Research on Mitigation	CIAT, CIFOR, CIMMYT, ICARDA, ILRI, IRRI, ICRAF, Worldfish
- Research on Adaptation	BIOVERSITY, CIFOR, CIMMYT, CIP, ICARDA, ICRISAT, IFPRI, IITA, ILRI, IRRI, IWMI, ICRAF, WARDA, Worldfish
Spatial Scale	
- Global	BIOVERSITY, CIFOR, IFPRI, IWMI, ICRAF
- Regional	CIFOR, CIMMYT, CIP, ICARDA, ICRISAT, IFPRI, IITA, ILRI, IRRI, ICRAF, WARDA, WorldFish
- Country or local	IITA, ILRI, WorldFish

Table 2. Climate Change Analyses — Summary of CG Centre Research

Research Activity	CG centres involved
CLIMATE CHANGE IMPACTS	
- Biophysical Models	CIFOR (CO ₂ Sequestration), CIP, ICARDA, ICRISAT, ILRI, IRRI
- Mapping/Agroecological Approaches	CIAT, CIP, ICARDA, ICRISAT, IFPRI, ILRI, IRRI, IWMI, ICRAF, Worldfish
- Scenario Analysis	CIMMYT, CIP, IFPRI, ILRI, IWMI
-Ecosystem Interactions	BIOVERSITY, CIFOR
Downscaling of GCM (hydrologic data); Baseline Climate Data	BIOVERSITY, CIAT, CIP, IFPRI, ILRI, IRRI
ADAPTATION METHODS	
(Participatory, rural) Adaptation Strategies	CIAT (insurance, monitoring), CIMMYT, CIP, ICARDA, ICRISAT, IFPRI, IITA, ILRI, IRRI, IWMI, WARDA, Worldfish

(Eco)system Adaptation	CIFOR
Crop Improvement and Breeding for Climate Change [individual crops]	BIOVERSITY, CIAT, CIMMYT, CIP, ICARDA, IITA, IRRI, ICRAF (identifying Plant Phenology), WARDA

Note: Given that the information in the text is not complete, the information in Tables 1 and 2 is likely also incomplete.

The following research activities are listed by Centre under three headings:

- 1) Current Research Areas (on or related to climate change)
- 2) Ongoing Research Projects (on or related to climate change)
- 3) Research Plans (for climate change) [if provided]

No attempt has been made by the CG Centres or by the editor to present a complete picture of all ongoing (and particularly not all planned) activities related to climate change. While partial and incomplete, this document still provides a useful overview of the current status and focus of the various Centres.

1. Africa Rice Centre (WARDA)

The Africa Rice Centre (WARDA) is the premier research Centre for rice development in Sub-Saharan Africa. It also serves as a hub for rice-related R&D networks in the region.¹

1.1 Current Research Areas

WARDA focuses on the poorest communities, which are also the most vulnerable to climate change. Through its research on securing the productivity of fragile agricultural systems by developing new varieties and complementary technologies, WARDA seeks to not only increase productivity but also decrease the risk of harvest failure due to climatic or biological factors (e.g. pests and diseases).

Current research activities related to climate change include developing varieties that are adapted to dry environments, tolerant to heat, cold and salt stress, and developing complementary integrated natural resource management (INRM) practices.

Some of the research areas WARDA focuses on are:

1.1.1. *Adaptation: breeding for climate change:*

- Breeding improved inter- and intra-specific lines and varieties with good response to climatic stresses for use in irrigated, upland, and lowland rice-based systems in Africa. Irrigated areas are particularly prone to cold and heat stress whereas rain-fed areas are subject to drought (upland and lowland ecosystems), flooding, weed competitiveness, and iron toxicity (lowlands). These are all related to climate change and are partly triggered by the changing conditions observed in Africa in the early 1970s and 1980s;
- Breeding new ecosystem-specific varieties with resistance, tolerance, or competitiveness to one or more of the prevalent stresses (parasitic and non-parasitic weeds, African rice gall midge, rice yellow mottle virus, blast, and iron toxicity); and
- Characterising genes and molecular markers for tolerance and resistance to the aforementioned biotic and abiotic stresses.

¹ See WARDA website (<http://www.warda.org/>) for more details.

1.1.2. *Adaptation: crop system level*

- Supporting cropping system diversification for income improvement and risk reduction with an emphasis on vegetables and the sustainable management of tree crop systems in inland valley rice ecologies; and
- Documenting local knowledge and innovations as well as the evaluation and dissemination of promising practices, resulting in a better utilisation of existing farmer knowledge for finding adaptable solutions to complex problems.

The Centre is also engaged in the following projects that are specific to climate change:

1.2 Key Research Projects

1.2.1 *Major drought profiles in rain-fed rice characterised for Africa*

- Develop regional typology of drought profiles and associated stresses for rain-fed rice ecosystems
- Assess interactions between drought and other biotic and abiotic factors in rain-fed rice ecosystems
- Assess the likely impacts of climate change on drought occurrence for rain-fed rice

1.2.2 *Improved drought-tolerant lines and cultivars with higher and stable yield*

- Morphological and physiological evaluation of indigenous germplasm and intra- and interspecific breeding lines for drought tolerance
- Characterise genes and molecular markers for drought tolerance
- Develop and evaluate drought-tolerant/resistant germplasm for rain-fed rice

1.2.3 *Integrated management options to mitigate drought*

- Inventory of existing cultural practices that contribute to rain-fed rice yield stability under drought
- Field testing and evaluation of integrated drought management options (combining variety and cultural practices) for rain-fed rice ecosystems

1.2.4 *Strategies for mitigating the impact of climate change on rice-based livelihoods in SSA*

- Assess the impact of climate change on the livelihoods of rural populations
- Develop strategies that mitigate the impacts of climatic change on the livelihoods of rural populations
- Regional and expert consultation workshops to develop options for rehabilitating environmental assets for rural communities

1.3 Research Plans

1.3.1 Adapting to drier climates

New initiatives focus on improved INRM (Integrated Natural Resource Management) practices for use in a predicted drier climate, like conservation farming, water conservation technologies, and water harvesting technologies.

Inland valley development will receive special emphasis. Climate change will increase pressures on inland valleys such that areas in inland valleys that are already in use will intensify, while presently pristine areas will be opened up to agriculture. WARDA has a comparative advantage for working in this ecology because it convenes the Inland Valley Consortium (IVC), one of the oldest ecoregional programs of the CGIAR. The IVC has been involved in inland valley research and development issues since its inception in 1993.

A major component will be research investigating the adaptation by the local population to climate change, through migration, shifting to different ecologies, or shifting land use patterns.

1.3.2 Agronomic and spatial modelling tools

Modelling techniques, including GIS and crop growth models, are considered to be important tools for research on climate change at WARDA. It is envisaged that the predictions and forecasts of renowned climate-research institutes will be used as input for existing WARDA crop growth models, like ORYZA and RIDEV. Modelling and GIS will serve as geospatial tools to direct and support breeding activities and INRM research, as well as determining the areas that are most likely to be subject to major negative impact of climate change.

2. Bioversity International

Bioversity is the world's largest international research organisation dedicated solely to the conservation and use of biodiversity.²

2.1 Current Research Areas

Current research areas focus on identifying climate change impacts on crop wild relatives, rapid characterisation of ex situ collections for breeding for future stresses, and climate data collections for further analysis.

2.2 Key Research Projects

2.2.1 *Climate change impact on major genepools of crop wild relatives*

Impact study of climate change on major genepools of crop wild relatives with critical analysis of conservation implications (in situ and ex situ). (Contribution to issues series by Inter-Centre Working Group on Climate Change, to be published in Agriculture, Ecosystems and Environment journal.)

2.2.2 *Collection of baseline daily climate data for characterising current climates and comparing with downscaled GCM scenarios (joint with CIAT)*

This involves the collection and processing of daily data from climate stations around the world (23,000 different stations from the GSOD database), and collation of TRMM satellite-derived rainfall measurements across the globe. Currently ongoing research which will result in peer-reviewed publication.

2.2.3 *Climate change scenarios data (with IRRI and CIAT)*

This involves the collation and modelling of future climate scenarios to have high resolution (1km) surfaces of changes in climate as modelled by global circulation models. This data is being made available as part of the WorldClim product.

2.2.4 *Rapid characterisation methods*

Rapid characterisation methods for ex situ collections for identifying possible abiotic adaptations useful for breeding for future climate stresses (example – beans, tropical forage species). This work uses the climate at point of collection to rapidly screen an ex situ collection for possible adaptations useful for crop breeding for greater resistance to abiotic stresses that will augment in magnitude with climate change. Peer-reviewed articles have been submitted on this work.

² Additional information can be found at <http://www.bioversityinternational.org/>.

2.3 Research Plans

2.3.1 *How well will current conservation strategies address changing agricultural and biodiversity needs due to changed climate conditions?*

Climate change is causing species extinction, range shifts, alterations to biological cycles, and compositional and structural changes in ecosystems. This will have profound implications not only for the species themselves but for the dynamics of ecosystems and the services they provide to people and agriculture, such as pollination, timber and non-timber forest products, and clean air and water. How well are we prepared to adequately conserve important wild species and ecosystems using integrated ex situ, in situ, and human intervention strategies? In order to respond effectively to climate change impacts, we need to:

- Assess vulnerability to climate change of selected important wild species including crop wild relatives and priority forest tree species, and their habitats;
- Identify areas where there is overlap between current and future habitat as defined by climate scenarios;
- Devise strategies for effective selection and maintenance of important wild species in current or new reserves in these locations;
- Understand the impacts of climate change and habitat fragmentation on gene flow, spontaneous regeneration, and ecosystem goods and services that are essential to sustainable agriculture and food systems;
- Identify wild species and populations that possess climate-adapted traits for use in crop breeding;
- Identify important species that are highly vulnerable to climate change impacts and for which ex situ or relocation strategies are a viable option; and
- Develop systems to ensure maintenance of essential goods and services for agriculture.

Pipeline Projects

1. Genetic Erosion: "Status, trends and valuation of agricultural biodiversity for effective conservation decisions and actions." UNEP/GEF PDF-B proposal.
2. Review/re-analyse the existing provenance trials of forest trees in Europe in collaboration with IUFRO to develop new guidelines for transfer of forest reproductive material at pan-European level to facilitate migration/adaptation of trees in the face of climate change.

2.3.2 *Diversification: reducing risk of loss of crop yields and quality from irregular climate*

It is known that irregular and extreme climate events impact crop yields, and a number of studies have shown that increasing temperature and rising carbon dioxide levels reduce nutrient content. The process and outcome of crop diversification to mitigate these impacts has been rarely researched. Yet understanding the mechanisms and reasons behind adoption of diversification measures is critical for promoting adaptation strategies to reduce risk of impacts of climate change. This would include

- Documenting evidence and producing case studies of farmers who are adapting crops, cultivars, and farming regimes to cope with the increased risk associated with irregular climate. For example, selecting faster maturing varieties for shorter growing seasons and planting different tree species with different levels of tolerance/resistance to different intensities of extreme climatic events such as flood, cyclone, and drought,
- Identifying and quantifying the role of non-climatic factors (e.g. economic conditions, institutional arrangements, technology, and social influences) in crop adaptation decisions, and
- Evaluating the impact of such diversification measures for adaptation on livelihoods in terms of food security, nutrition, human health, and sustainable livelihoods.

2.3.3 *Matching climate-vulnerable crops with their climate-tolerant wild relatives and land races*

- Identify areas where selected crops and socioeconomically important tree species will be adversely impacted by climate change using climate change models,
- Identify areas where CWR and landraces are tolerant of the same climate conditions that will impact crops (i.e. climactic ecotypes), including extreme and periodic events such as high-intensity storms, droughts and floods,
- Identify gaps in the CGIAR collections of these ecotypes and target these species for collection (SINGER to facilitate information on collections and characterisation of traits in collaboration with other Centres),
- For tree species, identify climatically better-adapted provenances, or alternative species, and undertake germplasm collections and trial plantings.

3. CIAT (International Centre for Tropical Agriculture)

CIAT conducts socially and environmentally progressive research aimed at reducing hunger and poverty and preserving natural resources in developing countries.³

3.1 Current Research Areas

CIAT's work on climate change includes impact studies (agricultural productivity, wild species, vulnerability mapping, risk assessment and monitoring mechanisms), adaptation research (crop improvement and more recently participatory techniques for developing risk management strategies), and mitigation research (carbon balances, quantification of sinks, promotion of management options that minimise carbon/methane emissions). Some of the most recent highlights from CIAT's portfolio of climate change research are:

- *Crop improvement*: Results of a long-term breeding program for drought resistant beans
- *Risk Management*: Weather-based insurance schemes for smallholder farmers
- *Climate Change Impact*: Detailed maps of agricultural productivity now and in the future for a number of crops, based on crop models and GCM scenarios
- *Climate Change Monitoring*: Protocols for national scale monitoring of climate change impact

3.2. Key Research Projects

CIAT's research portfolio⁴ over the last few years has included several projects related to climate change. These range from a dedicated project that focuses exclusively on climate change called "Confronting Global Climate Change," as well as a number of studies housed in other CIAT projects. Projects include, in particular:

3.2.1 *Rice improvement for Latin America and the Caribbean*

- Incorporating foreign genes as novel sources for increased efficiency of water use in rice

3.2.2. *Tropical grasses and legumes*

- Developing grass and legumes genotypes with superior adaptation to edaphic and climatic constraints
- Identifying genotypes of grasses and legumes with dry season tolerance
- Developing shrub legumes with adaptation to acid soils and drought

³ For more information, see: <http://www.ciat.cgiar.org/>.

⁴ Based on Annual Reports 2003–present.

- Developing legumes for multipurpose use in different agroecosystems and production systems
- 3.2.3 *Beans and cassava*
- Improving cultivars with enhanced water use efficiency
- 3.2.4 *Confronting global climate change*
- Developing crop, forage, water, and soil management to minimise sources and/or increase sinks of GHG
 - Adapting germplasm and management systems to changing climate conditions and exacerbated incidence of pests and diseases
 - Breeding beans with greater drought resistance
 - Assessing the response of critical ecoregions, populations, crops, and crop wild relatives to changing climates
- 3.2.5 *Tropical Soil Biology and Fertility Institute of CIAT*
- Developing sustainable land management for social profitability, with special emphasis on reversing land degradation
 - Developing or identifying systems that contribute to carbon sequestration and mitigate greenhouse gas emissions
 - Initiating payment for environmental services in the Fuquene watershed (Colombia): carbon stocks and fluxes of greenhouse gases
 - Enhancing the productivity of crops and grasses while reducing greenhouse gas emissions through bio-char amendments to unfertile tropical soils
- 3.2.6 *Communities and watersheds*
- Introducing and evaluating new genetic materials of annual crops in the Luquique reference site, Honduras
 - Studying the impact of climate and land use change on water resources: availability, use, and management
 - Developing protocols to monitor climate change trends and simulate impacts in high mountain ecosystems
- 3.2.7 *Land use*
- Generating baseline high-resolution climate data for the globe: WorldClim and downscaling of future climates from GCMs
 - Analysing and predicting vulnerability of land use systems to significant external events. Farming Futures: Modelling the effects of climate change on agriculture
 - Generating information on and insight into biological limitations and drivers of land use change: wild beans and climate change
 - Comparing deterministic and probabilistic algorithms for prediction of landslides caused by extreme climatic events

- Analysing and predicting the vulnerability of land use systems to significant external events: Spatial analysis of household vulnerability to El Niño in coastal Ecuador
- Developing a method of site-specific drought insurance for Bean farmers in Honduras
- Developing drought insurance for poor farmers in developing countries – two case studies
- Generating climatic data and tools for risk mapping as an aid to FAO Farmer field schools in the semi-arid areas of Kenya

4. CIFOR (Centre for International Forestry Research)

CIFOR contributes to the sustained well-being of people in developing countries, particularly in the tropics, through collaborative strategic and applied research and related activities in forest systems and forestry, and by promoting the transfer of appropriate new technologies and the adoption of new methods of social organisation for national development.⁵

4.1 Current Research Areas

4.1.1 Adaptation to climate change

Major CIFOR activities fall under a large project, “Tropical Forests and Adaptation to Climate Change” (TroFCCA), that operates in three continents. Other activities related to adaptation include research on the impact of climate change on ecosystem services and impacts of climate-related hazards (flooding, fire) on forested ecosystems. The main research topics are:

4.1.2 Avoided deforestation, land use, and land-use change

Previous CIFOR research projects “Underlying causes of deforestation” and “Policies, technologies and global change” produced an array of publications on underlying causes of deforestation. Currently, and based on earlier work, the research focuses on avoided deforestation as an option for post 2012 UNFCCC.

4.1.3 Forest carbon, carbon sequestration

The CIFOR research under this heading aims at developing methodologies for assessing forest carbon pools and developing methods and tools for carbon projects and for carbon management in forestry.

4.1.4 Forest ecosystem services

The CIFOR research under this heading includes generic work on forest ecosystem services, including rewarding mechanisms and their role in improving rural livelihoods. Studies on forest rehabilitation are also included here.

4.2. Key Research Projects

Under Adaptation to Climate Change:

4.2.1 Ecosystem resilience and vulnerability

⁵ <http://www.cifor.cgiar.org/>.

- Focusing on increased vulnerability of the poor to climate change through a) exposure to more frequently occurring climate-related natural events and hazards (e.g. droughts, floods, fire), and b) impacts on long-term productivity of the land (e.g. precipitation patterns etc.)
- Studying the impact of climate change on ecosystem services (water, biodiversity, carbon etc.)
- Developing a set of robust methodologies to assess vulnerability of forested ecosystems to climate change
- Examining underlying causes and impacts of forest fires—management and policy recommendations to reduce unwanted fires and minimise the negative impacts of them
- Studying local, regional, and global impacts of disturbance regimes (e.g. fires) on the tropical peatlands (e.g. Indonesia)

4.2.2 *Adaptation strategies—best practices*

- Defining adaptation strategies that will take into account the way in which diverse landscapes provide many environmental goods and services, and satisfying the needs of a wide range of stakeholders
- Identifying key stakeholders and their existing coping mechanisms

4.2.3 *Criteria and indicators (C&I) for adaptive management*

- Assessing central, forest-related issues of development, such as food security (long-term changes in productivity), energy supply (e.g. wood and other biofuels), watershed management (e.g. water supply, hydropower), and peatlands management
- Testing of C&I in particular systems

4.2.4 *Mainstreaming adaptation into policies*

- Developing policies that will help to adapt to climate change. Research includes perspectives of different policy actors and strengthening of policy-science dialogue through consultation

4.2.5 *Synergies between adaptation and mitigation*

- Developing best practices for promoting synergies between adaptation and mitigation measures and between different ecosystem services in landscapes
- Identifying trade-offs and options for different landscape management in the light of climate change adaptation and mitigation

Under avoided deforestation, land use, and land-use change:

4.2.6 *Underlying causes of deforestation*

- Analysing main socioeconomic and policy drivers of tropical deforestation.

4.2.7 *Potential role of forests in post 2012 UNFCCC/Kyoto Protocol*

- Producing CIFOR's background document to UNFCCC and other studies on reducing emissions from deforestation in developing countries highlighting constraints, policy options and challenges for the future

4.2.8 *Potential implications for people and forests*

- Maintaining and increasing forest carbon pools through improved management methods to manage forests more effectively for multiple goods (wood, etc.) and services (carbon sequestration)

Under forest carbon, and carbon sequestration

4.2.9 *Role of forests in global carbon cycle*

- Improving methods for assessment of forest carbon through, for example, development of models for estimating carbon content of trees and forests based on easily measurable variables through allometric equations, among others

4.2.10 *Development of methods and tools for carbon management and for facilitating the implementation of carbon forestry projects*

- Generating models: CO2Fix model for carbon sequestration in forested ecosystems. CO2Fix is the most widely used carbon sequestration assessment tool in the world. It's the only simulation model currently approved in the CDM methodology
- Monitoring systems for carbon and other environmental services of forests
- Creating methods and tools for carbon management through participation in the IPCC processes on the assessments and methodologies (e.g. Good Practice Guidance for LULUCF, etc.)
- Strengthening carbon sequestration projects—facilitating the development of Project Design Documents for forestry CDM projects in Indonesia and Latin America (FORMA project)
- Maintaining CIFOR's forest carbon web page (www.cifor.cgiar.org/carbofor) providing an information clearing house on forest carbon issues

4.2.11 *Impacts on rural poor*

- Studying impacts of carbon projects from the perspective of sustainable development objectives

Under forest ecosystem services

4.2.12 *Development of methods for integrated management of environmental goods and services in forested catchments*

- Examining interactions between biophysical and socioeconomic properties of catchments to better understand the cause–impact chains at patch and landscape scales and the ecological and socioeconomic variables affecting land-use

- Developing improved land use planning for different landscapes in terms of livelihood needs and biodiversity values
- Devising participatory methods and approaches to improve multistakeholder collaboration and planning processes with emphasis on livelihood needs and incentive mechanisms for adaptive landscape management

4.2.13 Markets for environmental services of forests—impacts on rural livelihoods

- Creating synergies and conflicts between local livelihood needs and global conservation goals
- Developing reward systems (payments etc.) for environmental services (carbon, water etc.) of forests—impacts on local livelihoods.

4.2.14 Forest rehabilitation and landscape restoration

- Promoting rehabilitation of degraded forest landscapes and integration of rehabilitation into national and regional environmental conservation strategies by developing best practices and appropriate activities.
- Rehabilitating fire-prone areas.

5. CIMMYT (International Maize and Wheat Improvement Centre)

CIMMYT is committed to improving livelihoods in developing countries. Through strong science and effective partnerships, we create, share, and use knowledge and technology to increase food security, improve the productivity and profitability of farming systems, and sustain natural resources.⁶

5.1 Current Research Areas

Research-for-development activities at CIMMYT that address climate change (adaptation and mitigation strategies) include:

5.1.1 Genetic enhancement

- Screening maize, wheat, and triticale germplasm for adaptation to heat-prone environments
- Identifying bio-nitrication inhibition (BNI) in wild species that can be used for genetic enhancement of wheat (adaptation strategy)
- Breeding for heat- and drought-tolerant maize and wheat [both through conventional genetic enhancement and biotechnology] as well as for emerging crop pests as a result of climate change (adaptation strategy)

5.1.2 Crop and natural resource management

- Promoting conservation agriculture in maize- and wheat-cropping systems by tailoring resource conservation technology; e.g. zero- or reduced-till (both adaptation to heat and less water by shortening cropping cycles and saving resources, and mitigation CO₂ releases)
- Using precision agriculture (infrared sensor) for appropriate management of inputs, e.g. N-fertiliser (mitigation strategy)
- Undertaking crop residue viz. a viz. its use as livestock feed or bio-energy raw material (mitigation strategy)
- Breeding crops that fit into conservation agriculture systems; e.g. ability for performing after direct-seeding/zero-till, or in bed-planting or lower input use (adaptation strategy)

5.1.3 Impact, targeting, and assessment

- Developing crop scenarios for maize and wheat under less water and hotter environments that will assist in developing both adaptation and mitigation strategies
- Conducting ex-ante analysis of technology [interventions] options under maize- and wheat- cropping system scenarios affected by climate change;

⁶ For more details, see: <http://www.cimmyt.org/>.

- e.g. bio-fuel that will assist CIMMYT and partners to organise their research portfolios as well as build impact pathways in any follow-up undertaking for adapting or mitigating climate change
- Monitoring maize- and wheat-technology exchanges in relevant cropping systems (that may be affected by water scarcity or heat, or whether new technology that address climate change mitigation or adoption being used), and measuring impacts on livelihoods due to adaptation to, and mitigation of climate change

6. CIP (International Potato Centre)

The International Potato Centre (known by its Spanish acronym, CIP) seeks to reduce poverty and achieve food security on a sustained basis in developing countries through scientific research and related activities on potato, sweetpotato, and other root and tuber crops, and on the improved management of natural resources in the Andes and other mountain areas.⁷

6.1 Current Research Areas

6.1.1 *Human dimension*

For the last 10 years, the NRM Division has been collaborating with the University of Missouri-Columbia and most recently with the Environment Group of the World Bank to address some human dimension issues directly related to climate change.

6.1.2 *Process-based crop modelling*

This research area focuses on the analysis of crop responses to changes in climate and management.

6.1.3 *Developing crop management models and strategies for coping with climate change*

During the last decade, CIP has carried out research projects related to integrated disease and insect management (IDM and IPM respectively). Currently this type of research is part of the Integrated Crop Management Division. Researchers have focused on improving the understanding of the biology, epidemiology, and dynamics of potato and sweetpotato pest (pathogens and insects) populations, and on developing management technologies adapted to small-scale agriculture.

6.1.4 *Trade-off analyses*

As a tool to analyse complex systems, the TOA model constitute an important tool in climate change research and in understanding its impact on agriculture and natural resources.

6.1.5 *Spatial-temporal scaling of climate data*

Climate change research relies on the use of complex models to develop scenarios of future climate events. A major bottleneck in utilising climate forecasts in agriculture, particularly resource-poor agriculture and their expected

⁷ <http://www.cipotato.org/>.

behaviour under climate change conditions is the spatial scale of climate forecasts. The data are packaged in grids of 100 km x 100 km or coarser, making it difficult to link them with crop growth models requiring higher resolution climate data.

6.2 Key Research Projects

6.2.1 Human dimensions in climate change analysis

- Developing methodologies to elicit farmer's perception regarding climate variability and change
- Characterising and describing local use of climate and weather indicators, the managers of knowledge, and the users of information (when and who incorporates this information into decisions, e.g. when to plant, where, what, how much)
- Developing weather and climate information networks, identifying the nodes of information used in decision making
- Coping and adapting strategies used by farmers
- Conducting vulnerability assessments at the household and community levels (perceptions and risk ranking within a livelihood strategies, and sustainable livelihoods framework)
- Developing on-going strategies and assessments of climate resilient interventions (e.g. tolerant varieties)

6.2.2 Process-based crop modelling

- A potato (*Solanum*) model has been developed and parameterised with experimental data from the Andes. Most important cultivated and native varieties are already included. A growth chamber with fully computerised temperature and ferti-irrigation controls (CO₂, and PAR lights for simulating day-lengths are being implemented) is being used to parameterise the model with CIP genetic materials and their response to changes in climate and management.
- This model is coupled to a GIS to generate spatial analyses of the expected outcomes in potato production as a function of variations in soil, management practices, and climate.
- A sweetpotato model is under construction. The first version should be available in 2007.
- A contact has been made with the University of Florence to initiate testing of free air carbon dioxide enrichment systems in the Andes.

6.2.3 Crop management models

- Currently, models for simulating disease and insect development under different agroecological conditions have been developed. The potato late blight model predicts disease severity according to temperature and

- relative humidity; the model has also been used to predict the amount of fungicide that would be needed to control the disease. This model has been used within a GIS and can be used to understand the potential change (increase or decrease) of the disease with, for example, changes in temperature and rainfall patterns that are likely to occur due to climate change. This understanding would help to develop, adapt, and disseminate coping strategies such as new resistant cultivars or appropriate fungicide regimes in the most affected areas.
- The phenology model for the potato tuber moth (PTM—one of the most important invasive potato pests) predicts insect population development in different agroecosystems and when linked to GIS, forecasts the worldwide and regional distribution potential of the pest and serves as a decisionmaking tool for appropriate pest-management practices in different agroecosystems.
 - In addition, researchers are constantly monitoring known, emergent, and re-emergent viruses, particularly those that can be transmitted by insect vectors, such the Potato Yellow Vein Virus (PYVV), which has rapidly spread south from Colombia to Northern Peru in just a few years. This epidemiological knowledge, coupled with models capable of forecasting future distribution of vector insects, such as aphids, whiteflies, and psyllids, will be critical in predicting the effect of climate change on the potential spread of dangerous viruses worldwide. Changes in vector population and distribution have already been observed during El Niño years in Peru, for example.

6.2.4 Trade-off Analysis

CIP is part of the Trade-off Analysis project funded by USAID and led by Montana State University. This group developed the Trade-off Analysis (TOA) Model (full and minimum data versions). The Trade-off Analysis Model is based on spatially-explicit econometric simulation models linked to spatially-referenced biophysical simulation models to simulate land use and input use decisions and their impact on the environment, poverty, human health, and food security, for example. It is a policy decision support system designed to quantify tradeoffs between key sustainability indicators under alternative policy and technology scenarios. The results are presented in the form of trade-off curves that are intuitive and easy-to-understand for policymakers using the economic principle of opportunity cost. A TOA application has been made in West Africa incorporating the Century model to capture long-term carbon sequestration.

6.2.5 Multi-Scaling Tools for Climate Related Research

CIP has been quite active in the development/testing of multiscaling tools for climate-related research. Some of the ongoing research projects and products developed are listed below:

Climate interpolation models: These include incoming solar radiation, maximum and minimum temperatures, and rainfall. The models use spatial and temporal distribution of the atmospheric transmissivity in complex terrains combined with net radiation balance for temperature interpolation and a digital mountain wave model to interpolate rainfall.

Rainfall reconstruction protocol: Changes in vegetation greenness, monitored with space-borne satellites, and rainfall measured in weather stations are jointly processed using Fourier and Wavelet transform to determine patterns and characteristic noise and then used to reconstruct rainfall throughout the extrapolation domain of the weather station in 1km resolution grids. A similar protocol is being developed for maximum and minimum temperature. These protocols complement the climate interpolation models.

In collaboration with the University of Connecticut/IRI, CIP is evaluating downscaling methods for climate prediction. CIP is testing multifractal and wavelet transform methods for downscaling climate data in the highland region of the Andes. Initially these methods will be tested using monthly gridded observations, to be followed by daily observation and tests on climate model predictions for the 21st century. This seems to be one of the most appealing non-linear methods to approach the scaling problem. The reason why it has not been widely used is because the computation is cumbersome. The NRM team has developed software to do the analyses and is developing the applications with climate change research groups.

7. ICARDA (International Centre for Agricultural Research in the Dry Areas)

ICARDA's mission is to improve the welfare of poor people and alleviate poverty through research and training in dry areas of the developing world, by increasing the production, productivity, and nutritional quality of food while preserving and enhancing the natural resource base.⁸

7.1 Current Research Areas

The main focus of ICARDA's work is to help land users cope with climate change in the mainly rain-fed production systems of the non-tropical drylands. The climate change related work at ICARDA can be categorised under four main themes:

7.1.1 *Utilisation of genetic diversity and plant improvement*

Genetic diversity (adaptation)

- Characterising the genetic diversity of traits for extreme temperature and drier climates (adaptation and mitigation). Includes identifying and incorporating genes responsible for adaptive traits relevant to climate change.
- Evaluating, selecting, and conserving the genetic diversity of traits for extreme temperature and drier climates (adaptation and mitigation). Includes use of an integrated “tool box” approach to conserve and characterise global genetic resources for dryland crops and wild relatives. These resources provide the diversity necessary for finding genes that will allow agricultural plants to cope with the changes in growing conditions. In-situ conservation of valuable species allows for the monitoring of population and species change in the given environs.

Plant improvement—Improved biotic and abiotic resistance and adaptation to climate change (adaptation)

- Undertaking genetic enhancement for drought tolerance in lentil and chickpeas. Accessions with drought tolerance have been identified and utilised in breeding programs to construct new genotypes with traits for better adaptation to drought-prone environments.
- Barley is known for its relative ability to withstand drought conditions to produce grain and biomass. The progress made in drought tolerance research at ICARDA proved that it is realistic to develop varieties that have increased yield under drought-prone conditions.
- The identification and genetic mapping of quantitative trait loci (QTL) for drought tolerance are currently receiving greater research focus. This approach provides a powerful tool to dissect the genetic basis of drought

⁸ <http://www.icarda.org/>.

tolerance. If integrated in marker-assisted breeding programs, this will allow gene pyramiding and accelerate the development of drought-tolerant genotypes. Further multidisciplinary research integrating plant breeding, physiology, and molecular genetics is now in progress to realise the potential of these approaches and increase the efficiency of crop enhancement in drought-prone environments. Examples are the BMZ-funded project “Exploration of genetic resources collections at ICARDA for adaptation to climate change: Identification and utilisation of sources of stress tolerance,” and the EU-funded project “Mapping Adaptation of Barley to Drought Environments (MABDE).”

- Heat and drought stress will affect not only yield but also end product qualities such as milling and processing of durum wheat. A breeding program is developing drought- and heat-tolerant genotypes as well as genotypes better adapted to rotation with legume crops in order to improve overall soil fertility and soil moisture retention. This work involves conventional breeding, stress physiology, and molecular marker tools, and the identification of QTL’s linked to stress. In addition the program is examining pest and disease interactions.
- Grasspea (*Lathyrus sativus* L.) is a drought- and salinity-tolerant food legume used by the rural poor particularly when other food sources are scarce. However, it contains high levels of a neurotoxin that result in crippling illness. Varieties have been developed with increased yield potential, drought tolerance, and reduced levels of neurotoxin that will benefit both human and animal nutrition under the extreme climatic conditions expected with climate change.

7.1.2 Crop-livestock production systems in dry areas

This research area focuses on crop rotations and conservation agriculture with specific emphasis on minimum tillage and mulch-based zero-till direct sowing and appropriate management of inputs for increased carbon sequestration and improved soil quality (adaptation and mitigation).

Another component is the diversification of production systems including small ruminant feed systems (adaptation and mitigation), integrating non-conventional sources of fodder and by-products into feeding systems that will allow farmers to cope with enhanced feed deficits. More intensified systems emerging from this integration will release pressure on rangelands, which will halt land degradation and improve range productivity.

7.1.3 Natural resources management

- Improved soil and water conservation in dryland production systems (adaptation and mitigation)
- Improved water use efficiency for rain-fed and irrigated production systems in drylands (adaptation)

- Integrated strategies to prevent and reverse land degradation of rangelands and sloping drylands (adaptation and mitigation)
- Integrated strategies to assess, prevent, and reverse salt-prone land degradation under rain-fed and irrigated agriculture (adaptation and mitigation)
- Assessment of water quality deterioration under dry environments, and development of approaches for improvement in water quality for agriculture, health, and environment

7.1.4 *Targeting and impact assessment*

Under this research area, land suitability, stressors (including climatic stressors), technology adoption, and natural resource valuation are implemented.

7.2. Key Research Projects

7.2.1 *Utilisation of genetic diversity and plant improvement*

- For example the GRDC funded “FIGS” project has identified a best bet sub-set of bread wheat landraces for drought resistance that are being tested under field conditions in Syria and Kazakhstan. The project examines GIS agroclimatic layers in the northern hemisphere—thus facilitating a more rational approach to selecting germplasm.
- The West Asia Dryland Agrobiodiversity project identified fruit trees, forage and pasture species, and wild crop relatives as potential sources of drought and high temperature tolerance. Similarly, the Arab Peninsular Regional Program has identified native species for rehabilitation of rangelands subject to high temperatures.
- Lentil genotypes with drought escape (early flowering and maturity, rapid biomass development, early ground coverage), dehydration avoidance (shoot and root traits) and dehydration tolerance have been developed and sources are made available to national programs through the ‘Lentil International Drought Tolerant Nursery (LIDTN). Similarly high yielding, drought and salinity tolerant chickpea genotypes are being disseminated throughout the non-tropical drylands via the Chickpea International Drought Tolerant Nursery.
- For barley, genetic sources of drought tolerance were identified and some of the associated traits have been well characterised. Using conventional and participatory breeding, drought tolerant barley genotypes were identified and released for use in farmer’s fields. Participatory plant breeding is a methodology particularly suitable for adapting crops to climatic changes because it operates on a much wider scale of target environments than conventional breeding and hence increases the probability of exposing breeding lines to environments where the changes occur.

7.2.2 Crop-livestock production systems in dry areas

- Double cropping and relay cropping in irrigated agriculture in Central Asia and the Nile Valley (mitigation)
- Introducing food and forage legumes and oilseed crops into former monocropping production systems
- Reducing and eliminating summer fallowing in Central Asia and in highlands of West Asia and North Africa particularly in highlands by introducing cover and cash crops and green manures (mitigation)
- Changing cultural practices for adaptation to different climate scenarios including times of sowing, seed rates, weed and pest management
- Adopting conservation agriculture with zero tillage for different rain-fed and irrigated cropping systems
- Developing early-maturing crops such as chickpeas and other legumes that can be planted during winter to avoid drought conditions and increase water-use efficiency, thereby almost doubling yields and allowing an expansion of the crop to drier environments. Selecting faba beans with reduced water requirements.
- Managing grazing systems in Central Asia (i.e. access to remote ranges to avoid overgrazing around villages) will avoid the deterioration of rangelands in that region and C sequestration
- Characterising small ruminant breeds to assess potentials for diversity (i.e. for milk production) and adaptive traits (i.e. fat tail, a feed store that allows sheep to cope better with feed scarcity during droughts)
- Increasing oilseed crops in cropping systems for biofuel energy requirements (adaptation and mitigation)

7.2.3 Targeting and impact assessment

- Agroecological zoning of Central and West Asia and North Africa (CWANA) (adaptation)
- Characterising and mapping climatic stress risk (drought, heat, cold) in agricultural areas of CWANA (adaptation)
- Mapping potential for water harvesting and supplemental irrigation in CWANA (adaptation and mitigation)
- Land suitability mapping for crop diversification in CWANA (adaptation)
- Valuing natural resources and payment for environmental services (adaptation and mitigation) linked to livelihood characterisation and poverty mapping
- Conducting technology adoption and impact studies to assess uptake, constraints to adoption, and effectiveness and relevance of improved options (targeting and mitigation)

8. ICRISAT (International Crops Research Institute for the Semi-Arid Tropics)

ICRISAT serves the poorest of the poor in the semi-arid areas of the developing world. It uses science as a means to serve the poor, not as an end in itself—the human face of science and agricultural research with our partners.⁹

8.1 Current Research Areas

ICRISAT's current research is centred around three key components, summarised below:-

8.1.1 Current rainfall variability and future climate change

Climate variability and change is an important consideration for ICRISAT given its mandate for the improvement of rain-fed farming systems in the semi-arid tropics of the developing world. Many factors contribute to the current low levels of investment in these systems, but production uncertainty associated with between and within season rainfall variability remains a fundamental constraint to many investors and vulnerable communities who often over estimate the impact of climate-induced uncertainty. Climate change is very likely to make matters worse with increases in rainfall variability in the semi-arid tropics being predicted with a high level of confidence.

ICRISAT, together with leading donor support agencies, believes that for agricultural communities and agricultural stakeholders to adapt to climate change and the predicted future increases in climate variability, their ability to more effectively cope with the constraints and opportunities of current climate must first be enhanced. Climate-driven tools and approaches are now available that allow for a far better understanding, characterisation, and mapping of the agricultural implications of current climate variability and the development of both strategic and tactical climate risk-management strategies specifically tailored to stakeholders needs. ICRISAT, working with partners, promotes and engages in an integrated approach to climate risk management that brings new and proven tools to bear on:

- Decision-support frameworks that provide a longer-term strategic understanding of the temporal and spatial distribution of climatic variability and its impact on the probability of performance and profitability of existing and innovative agricultural practices
- Seasonal climate and agricultural forecasting that enables farmers and support agents to 'fine tune' long-term strategies and thus plan tactically and farm more effectively in the face of seasonally variable weather
- Providing information on the extent to which climate change is impacting, or is likely to impact, on the nature of climate variability and the implications for rain-fed farming systems and their future development and productivity

⁹ <http://www.icrisat.org/>.

8.1.2 Screening chickpea for heat tolerance

Heat tolerance is a key attribute required by post-rainy season crops such as chickpea and is thus of current importance and will be of increasing importance in the context of global warming. While current work does not place an emphasis on understanding the physiological mechanisms involved in heat tolerance, the screening of materials under rain-fed conditions tends to select for heat tolerance, and ICRISAT has achieved quite some success in Asia using this approach. For example, var. ICCV-2 is now widely grown in Myanmar and Southern India and is valued for its heat tolerance under such post-rainy season conditions.

8.1.3 Climate change and integrated pest management

Agroecosystems are expected to respond to climate change in several ways: 1) temperature limits of pest and natural enemy species, 2) redistribution of pests, 3) selection of new strains with varying virulence, 4) differential effects on pests-natural enemies, thus causing decoupling of natural control mechanisms, 5) changes in food availability resulting in pest shifts, and 6) changes in competitive interactions between crop and weeds.

Rising temperatures are likely to result in the availability of new pests and pest niches. With the current trends in global warming and climate change, it is likely that if measures and global collaborative efforts are not undertaken, most pests will have a cosmopolitan range wherever the climate is favourable and the hosts are available. Prediction of such changes and range and diversity in pests niches should help develop better control measures, as well as adapt IPM to minimise pest incidence.

8.2 Key Research Projects

ICRISAT has many ongoing projects (and several more under consideration by donors) in Africa and Asia in which climate risk management approaches are integral and in which other CGIAR centres are partners (project summary details are provided in Table 8.1). To further foster and promote such approaches, ICRISAT, jointly with ASARECA, currently facilitates a NEPAD-endorsed consortium of 15 national, regional, and international partners entitled *“Investing in rain-fed farming systems of Sub-Saharan Africa: Evaluating the agricultural implications of current climatic variability and planning for future climate change.”* ICRISAT, ICRAF, CIAT, IITA, IWMI, and ILRI are partners in this consortium.

Table 8.1: Climate variability and change Projects in which ICRISAT is involved (2005-2006) [The Lead Centre (LC) is identified].

Project Title	Consortium Members	Stakeholders and Project Partners	Countries involved	Project Status
<i>"Making the best of climate: Adapting agriculture to climate variability"</i>	ICRISAT, IRI	Univ. Nairobi (LC), KMD, ICPAC, EARO, FOFIFA, SOMEAH.	Kenya, Madagascar, Ethiopia	Funded by, ASARECA-CGS
<i>"An aflatoxin risk early warning system to improve nutrition, health and income in west African smallholder farms."</i>	ICRISAT (LC), AGRHYMET	IER-Mali, SARI-Ghana, Univ. Of Sherbrooke and Florida.	Mali, Ghana	Funded by CIDA/CCLF
<i>"Options for improved use of climate knowledge and technology in the southern rangelands of Kenya."</i>	ICRISAT (LC), CIAT, IMTR	District Forest and livestock Office and extension staff at Makueni, Kenya. KMD, KARI	Kenya	Funded by DMP
<i>"Providing climate-based decision support for farmers and agricultural concession companies in Mozambique"</i>	ICRISAT (LC), CIAT, ICRAF, Reading Univ.	Mozambique Leaf Tobacco, CIP, DPA, IIAM, EMPRENDA Alliance, USEBA, SNS and Mozambique Met. Service.	Mozambique	Funded by PROAGRI-MINAG (World Bank)
<i>"Managing uncertainty: Innovation systems for coping with climate variability and change"</i>	ICRISAT (LC), CIAT, ICRAF, Reading Univ.	ASARECA Networks, ILRI, ARC-Sudan, Univ. of Asmara, NARO-Uganda.	Sudan, Eritrea, Uganda and ECA	Under final review by ASARECA-CGS
<i>"Legume diversification in tobacco systems. Climate risk and market opportunities"</i>	ICRISAT, Reading University	NASFAM (LC), Malawi Met. Services	Malawi.	CN accepted, Full proposal invited by IDRC-RITC
<i>"Building adaptive capacity to cope with increasing vulnerability due to climatic change"</i>	ICRISAT, CIAT and ZMD	Midlands State University, (LC) CARE, Dunavant Cotton, CSIRO, AREX, ASP	Zimbabwe and Zambia.	CN accepted by CCAA. Full Proposal under development
<i>"Clues from landraces: Positioning local knowledge on plant management of climate uncertainty at the heart of adaptive agricultural strategies"</i>	ICRISAT-Mali (LC)	CIRAD, IUCN, AMEDD, CRA, IER, Univs. of Florida and Sherbrooke, SARI	Ghana, Mali, Niger and extension to WCA.	CN accepted by CCAA, Full Proposal under development
<i>"Managing risk, reducing vulnerability and enhancing productivity under a changing climate"</i>	ICRISAT, ASARECA-SWMNet.	Sokoine University of Agriculture, Tanzania. (LC)	Tanzania, Kenya, Ethiopia, Eritrea, and Sudan	CN accepted by CCAA, Full Proposal under development.

8.3 Planned Research

8.3.1 Integrated pest management under climate change

ICRISAT is working with colleagues from IITA, IRRI, CIAT, and CIMMYT to initiate work with the following objectives:

- Develop and use existing tools to enhance the management of pests in the face of global climate change to foster a more food-secure rural world
- Predict changes in pest abundance, distribution, and host plant interactions as a result of global warming
- Develop appropriate IPM technologies for crop protection in the tropics and subtropics

9. IFPRI (International Food Policy Research Institute)

IFPRI's mission is to provide policy solutions that reduce hunger and malnutrition.¹⁰

9.1 Current Research Areas

IFPRI is working on climate change as it relates to agricultural productivity and policy, food security, and natural resource management with a focus on adaptation to the adverse impacts of climate change. While some research on mitigation measures is taking place, its prominence in IFPRI's research portfolio is relatively minor. IFPRI's work on climate change aims to identify and reduce sources of vulnerability to both changes in mean climate conditions as well as changes in patterns of climate variability.

IFPRI's Global Change Program aims to shift focus so as to deliver a more comprehensive, consistent, and balanced approach to analyses ranging from drivers of change to human welfare and ecosystem outcomes. This balance is essential not only to maintain a clear representation of the pathways to ultimate development outcomes, but also because policy and investment choices must be informed by insights into marketing, food safety, nutrition, trade, and other factors, as well as ecosystem service tradeoffs, all of which need to be addressed in a comprehensive manner.

Prior to the establishment of climate change as a priority area within IFPRI's research portfolio, IFPRI convened an interdivisional working group that developed a series of working papers on ways in which climate change and variability are relevant to IFPRI's research mandate. Research at IFPRI has also explored the role of policy and information, such as climate forecasts, in helping farmers adapt to climate change.

A second avenue through which climate change has exerted influence on IFPRI's research priorities is IFPRI's revised research strategy titled "Toward Food and Nutrition Security," which is grounded in the context of the broader goals of the CGIAR, as reflected in the CG System Priorities. The objectives of IFPRI's strategy are thus to better respond both to new opportunities for enhanced food and nutrition security, as well as to new challenges and threats to food security, including global health crises and climate change. According to the strategy, research will "assess long-term scenarios for agricultural and natural resource adaptation strategies to changes in global climate and water cycles, including examining policy, investment, adaptation, and mitigation options to maintain environmentally sustainable pro-poor growth."

¹⁰ See also: www.ifpri.org.

In keeping with these objectives, IFPRI developed a new Global Change Research Program, “Global Food and Natural Resources: Strategies and Policies for Adapting to Global Change,” in 2005-2006. The program focuses on the articulation and evaluation of effective policies for promoting food security, poverty reduction, and enhanced environmental sustainability under global change by undertaking cutting-edge research on a range of issues related to global change and food security, from the main drivers of change to the implications and consequences of change on food security to the appropriate policy responses for addressing global change and its consequences in equitable and sustainable ways.

IFPRI also leads the Global and National Food and Water System research area of the Challenge Program on Water and Food, which includes research on climate change and adaptation research as they relate to water resource management and food production, among other topics. Furthermore, IFPRI maintains close dialogue with other institutes and research groups that examine the impact of global environmental change on food systems and human welfare, such as the GECAFS program in the United Kingdom and the International Research Institute for Climate and Society (IRI) at Columbia University in New York. Besides serving on the advisory committee for GECAFS, IFPRI researchers have undertaken research in some of the target, developing regions of GECAFS.

9.2 Key Research Projects

Tables 9.1 and 9.2 provide an overview of existing research partnerships and climate change and global change research in IFPRI’s Global Change Research Program and of ongoing and pipeline collaborative research in this area.

9.2.1 Quantitative analyses for global (change) assessments

IFPRI has been providing quantitative analysis of plausible outcomes for agriculture and food for several completed and ongoing international assessments on global water, food, and ecosystem services, in which climate change impacts are an integral part of the analysis. These assessments include

- the Millennium Ecosystem Assessment
- UNEP’s Global Environmental Outlook (GEO-4)
- International Assessment of Agricultural Science and Technology for Development (IAASTD).

9.2.2 Joint impact and adaptation research in rural Africa

At the regional and local level, IFPRI is implementing a project on Food and Water Security under Global Change: Developing Adaptive Capacity with a Focus on Rural Africa [Ethiopia and South Africa focus [<http://www.ifpri.org/themes/globalchange/globalchange.htm>]. This project

combines farm household survey data with basin-level, national-level, and global level analysis to develop adaptation strategies for rural Africa.

9.2.3 Modelling Tool Development

- Downscaling of future climate projections at regional and global scales and converting the downscaled climate change scenarios into hydrological impacts using a macro hydrology model.
- Extending its global water and food projections modelling framework, which already accounts for the implications of climate variability, to also account for the impact of climate change; and to closely couple its crop and livestock spatial analysis work (together with other CG Centres) with climate change impacts.

9.2.4 Database Development

There are several specific areas in which IFPRI is extending the public goods knowledge base in order to meet growing demands for decisions and actions that will ensure future food security and alleviate poverty under climate change:

Table 9.1: IFPRI Global Change Research Partnerships

Country	Institute/Organisation	Strategic Roles	Region
ARI			
Australia	Australian Bureau of Ag. & Resource Economics ABARE	Complementary global modelling with IMPACT for IAASTD scenarios	Global and Asia
Germany	University of Hamburg University of Kassel	Climate change adaptation study, linking Hamburg models to the IMPACT model Water resource and dynamic land use modelling.	S.Africa/ Ethiopia /rural SSA Sub-Saharan Africa
United States	University of Colorado University of Minnesota Virginia Polytechnic Institute and State University	A strategic research partnership in global modelling and climate change analysis. Collaboration on the ex ante, economic assessment change (e.g. Gates Foundation project and the DREAM model. Economic evaluation of pest and disease constraints and potential mitigating technologies	Global Developing countries Developing countries
Austria	International Institute for Applied Systems Analysis	Crop suitability assessment. Integrated modelling of climate change impacts.	Global
NARES			
China	China Centre for Agricultural Policy (CCAP)	Linking IMPACT analysis to country level scenarios for China. Will also contribute expertise toward disaggregating of IMPACT demand by income class	China
Ethiopia	Ethiopian Economic Policy Research Institute	Stakeholder analysis to identify key policy issues relating to vulnerability to global change	Ethiopia
India	National Council of Applied	Key linkage to IMPACT with a country-	India

	Economic Research (NCAER)	level CGE model to better illustrate gender impacts	
South Africa	Centre for Environmental Economics and Policy in Africa (CEEPA)	A key partner in carrying out empirical investigation of vulnerability to global change in the Limpopo basin of South Africa	South Africa
CGIAR			
Colombia	Centro Internacional de Agricultura Tropical (CIAT)	Validation of crop allocation results and spatial analysis and data for HarvestPlus	Developing countries
Italy	Food and Agriculture Organization of the United Nations (FAO)	Strategic cooperation on the IAASTD, the Millennium Ecosystem Assessment, and food and agriculture statistics.	Developing countries
Mexico	Centre for Maize and Wheat Improvement (CIMMYT)	Plans to combine research efforts to look at climate change impacts on global wheat systems	Indo-Gangetic Plains
Kenya	International Livestock Research Institute (ILRI)	Complementary analysis of livestock systems for IAASTD, enhancement of spatial mapping of livestock systems, and the modelling of feed resources	Developing countries
Philippines	International Rice Research Institute (IRRI)	Combining research efforts to look at climate change impacts on global rice/wheat systems	Global
Sri Lanka	International Water Management Institute (IWMI)	Common interests in analysis of global water use	CP on Water and Food basins
Kenya	World Agro-forestry Centre (ICRAF)	Planned to combine efforts to look at global outlook for agroforestry activities	Global
India	ICRISAT	Analysis of impact of global change on crops in semi-arid areas	Semi-arid tropics

Table 9.2: Existing and Pipeline Collaborative Research Related to Climate Change

Initiative/Centre	Project	Status
Non-CGIAR Initiative		
MA	Millennium Ecosystem Assessment— IFPRI provided projections out to 2100 for the agriculture sector, using climate change damping factors provided from Integrated Assessment (IA) models	Completed project [2001-2005]
IAASTD	Exploring Alternative Futures for Agricultural Knowledge, Science and Technology (KST)—uses IMPACT-WATER, second round includes climate change projections from IFPRI, first round uses IPCC partner results	Ongoing research project [2005-2008]
GECAFS	Global Environmental Change and Food Systems— relates Global Environmental Change with Food Systems and Outcomes	IFPRI is in the advisory group of this initiative
GEO-4	Global Environmental Outlook UNEP; scenario work includes climate change, IFPRI focuses on agricultural aspects	Ongoing research project [2005-2007]
Bill and Melinda Gates Foundation	Supporting Strategic Investment Choices in Agricultural Technology Development and Adoption—Includes economic assessment of agricultural technology including traits that are adaptive to climate change.	Ongoing research project [2006-2009]

Table 9.2: Existing and Pipeline Collaborative Research Related to Climate Change

BMZ	Food and Water Security under Global Change: Developing Adaptive Capacity with a Focus on Rural Africa [Ethiopia and South Africa focus]—Climate change impacts on agriculture and adaptation strategies using modelling tools	Ongoing research project [2005-2007]
USAID CGIAR linkage grant	Downscaling of GCM data to study local and regional impacts from changes in runoff	Ongoing.
US EPA	Greenhouse Gas Mitigation Options for the Agricultural and Livestock Sectors—jointly with US-EPA, using the IMPACT model to run scenarios for cultivation, feed, and irrigation practices that are used to generate abatement cost curves for GHG Mitigation	Completed in 2006
Borlaug LEAP Fellowship	Research on impacts of climate change on hydrological and biological processes, including modelling the response of natural vegetation and crops to GHG-induced CC as predicted by various global climate models participating in the IPCC's 4th assessment	Funded, with University of Connecticut
U. of Colorado	Downscaling of climate change impacts using IMPACT-WATER [for ADAPT project]	Completed
ASARECA	Examination of vulnerability to Climate Change within agricultural production systems and rural livelihoods in Burundi, Ethiopia, and Tanzania	Proposal submitted as lead institution, with country-level partners
ICID Working group on Climate Change	IFPRI is an accredited member	
UNFCCC	IFPRI is accredited	
Challenge Programs, System-Wide Programs & System-Wide Initiatives		
Challenge Program on Water and Food (CPWF)	IFPRI leads the Global and National Food and Water System Theme that includes a research area on climate change—water-food interactions and adaptation strategies	Ongoing research program [first phase: 2001-2008]
Generations Challenge Program	Geographic and production systems targeting and impact analysis (with CIAT and CIMMYT)	Concept note accepted
Climate Change Working Group	CGIAR System-wide Initiative—IFPRI was assigned role on policy related matters	Working Group now disbanded
Consortium on Spatial Information	CGIAR System-wide Initiative—IFPRI is a member. Lead Centre on Impact Assessment	Ongoing
Bilateral CG Initiatives		
IRRI	Climate change and rice systems	Proposal prepared (IRRI leadership)
CIMMYT	Adaptation scenarios to respond to climate change on wheat production systems	Proposal submitted to USAID (IFPRI leadership), search for joint postdoc in this area since 2005
CIAT	GLOW3—Gender, Livelihoods and Empowerment: Women Working for Women on Adaptation to Climate Change in Africa	Proposal prepared (CIAT leadership)

9.3 Research Plans

- IFPRI's focus will be to add value and rigor to the characterisation and quantification of the important drivers of global change, in order to improve the assessments of their individual and joint impacts on the welfare of the poor, as mediated through food, agriculture, and related natural resource systems.
- The second area in which IFPRI will make novel and unique contributions is by constructing plausible development scenarios that involve climate change, so as to improve the means by which stakeholders can fashion descriptive, informed, and nuanced visions of the future as a basis for examining the need for and the nature of appropriate interventions. Careful research on scenario development is needed if the evaluation of long-term intervention strategies is to be relevant and credible to decisionmakers. Key elements of that research are how best to reliably project likely trajectories of the drivers of change over time spans of strategic interest, and how best to elicit and compile information on potential intervention options and their likely pathways of impact.
- The third key area is in the development of more comprehensive and flexible analytical tools and linked data platforms for evaluating the impacts of change on production systems, productivity, food security, ecosystem services, livelihoods, and overall economic well-being. Significant challenges faced in this area include the span of factors across which the effects of change will potentially need to be represented—as well as the range of geographic scales over which the different processes and interventions might play out.
- The fourth area is the generation and dissemination of relevant empirical research findings on the impacts of global change, through improved capacity building and outreach methods which utilise multiple channels and appropriate media formats that best address the needs of decisionmakers, as well as policy and investment analysts, researchers, and concerned civil society representatives.
- In the area of modelling tools updates, IFPRI is working on including the impacts of increased carbon-dioxide concentrations on crop yields in its global water-food projections model.

To summarise, IFPRI's planned activities will focus on the articulation and evaluation of effective policies for promoting food security, poverty reduction, and enhanced environmental sustainability under global change by undertaking cutting-edge research on

- the drivers and uncertainties that will most impact food security, poverty, and environmental sustainability under global change;
- a range of plausible future trajectories of these major drivers of change and their impacts on food and agricultural systems;

- the implications of these alternative futures for the efficiency and resilience of global food and agricultural systems;
- the consequences of these changes in food and agricultural systems on the provision of ecosystem services; and
- strategic, cost effective (national and international) policy reforms and investments needed to enhance human welfare in equitable and sustainable ways under global change.

10. IITA (International Institute of Tropical Agriculture)

IITA is an Africa-based international research-for-development organisation, aiming to be one of Africa's leading research partners in finding solutions for hunger and poverty.¹¹

10.1. Current Research Areas

Climate change related research at IITA focuses on the following areas:

- Improving drought resistant crops through selection, breeding, and biotech
- Undertaking adaptation research through crop diversification and utilising more drought-resistant crops

10.2. Key Research Projects

10.2.1 Improved drought resistance of crops

- Enhancement of Food Security in the Northern Guinea Savanna of Nigeria through the Identification and Deployment of Drought Tolerant Maize Varieties: deployment and promotion of adapted maize cultivars with increased tolerance to drought in the northern Guinea Savanna of Nigeria through participatory methods and closer collaboration between researchers and end users.
- Unlocking Genetic Diversity in Crops for the Resource-Poor: establishing phenotyping protocols for drought for cowpea, cassava, musa, and maize.
- Unlocking Genetic Diversity in Crops for the Resource Poor: Gene Expression Profiling in Musa Species. utilising genes expression profiling methods to identify candidate-expressed genes from watered and deficit tolerating plant seedlings of Musa balbisiana.
- Generation Challenge Program (GCP): Identifying the physiological and genetic traits that make cassava one of the most drought tolerant crops: 1. Identifying morphological, physiological, and molecular traits related to drought tolerance mechanisms in cassava. 2. Selecting contrasting genotypes with regard to tolerance to drought environments, including those involving alternate episodes of drought and rewatering, and those timed to coincide with key yield-determining processes such as tuber set. Identifying molecular markers for drought tolerance traits via QTL and candidate gene mapping in cassava toward a more efficient breeding approach, and identifying genes that might eventually be useful in improving drought performance of crops beyond cassava. 4. Separating the physiological aspects of drought tolerance from other adaptive mechanisms (particularly insect resistance) which are most relevant in cassava grown under water stress conditions. 5. Assessing the benefits of

¹¹ <http://www.iita.org/>.

- transgenic over-expression of a gene for improved leaf retention introduced into the *Manihot esculenta* gene pool and its potential use for other crops. 6. Strengthening partnership with institutions involved in breeding programs for drought tolerance.
- GCP: Characterisation of genetic diversity of maize populations. Documenting global maize migration from the centre of origin. Generation of data on the functional characterisation of drought candidate genes and linked regions for maize and teosinte.
 - Developing and disseminating stress-tolerant maize for sustainable food security in West, Central, and East Africa. Developing locally-adapted cultivars of maize with increased tolerance to drought, low soil nitrogen, and Striga, and with resistance to stem borers. Developing, testing, and promoting farmer-use of complementary practices to ameliorate stress conditions. Strengthening NARS's capacity to develop stress-tolerant maize and complementary crop management. Accelerating the transfer of research outputs to farmers and promoting linkages with development projects.
 - Eat Orange!¹²: Breeding for beta carotene-rich, drought-tolerant sweetpotato for drought prone areas of Mozambique. Breeding and dissemination of improved drought tolerant BCRS varieties to farmers in drought-prone areas of Zambezia, Gaza, and Maputo.
 - Preparing IITA-cassava reference germplasm for association mapping and distribution. In vitro placement of IITA reference and selected drought-tolerant genotype germplasm. Multiplying the above germplasm in vitro. Certifying the above germplasm as disease-free. Exchanging the reference sub-set of IITA with that of CIAT and EMBRAPA.

10.2.2 Adaptation research through crop diversification and utilisation of more drought resistant crops

- Improving food security through integrated crop production system in the lower shire districts of Malawi.
- Promoting community-based disaster preparedness through support to the local seed system. Establishing a strong seed production system at the farmers' organisations level in selected areas of Lilongwe district, for further distribution to other drought-affected areas.
- Multiplying and distributing superior planting materials and evaluating germplasm for cassava in Mozambique. Transferring rapid multiplication and production of disease-resistant and economically viable cassava technologies to farmers in Nampula and Zambezia provinces.
- Promoting sustainable production of legumes in the Beira and Nacala Corridors in Mozambique (AIMS). Improving smallholder agricultural

¹² Eat Orange is the theme of a Helen Keller International (HKI) program to promote the cultivation and consumption of the beta-carotene-rich orange-fleshed sweetpotato in developing countries to improve food security and combat Vitamin A deficiency.

- farming systems, food security, and household incomes in project communities in Tete Province.
- Enhancing food security in the Northern Guinea Savanna of Nigeria through the identification and deployment of drought-tolerant maize varieties. Deploying and promoting adapted maize cultivars with increased tolerance to drought in the northern guinea savanna of Nigeria through participatory methods and closer collaboration between researchers and end users.
 - Conducting research on harmonised policies for increased commercialisation and trade among the SADC countries. The goal is to provide critical policy analysis leading to dialogue and enhancement of policies within selected SADC countries.
 - Countries such as Mozambique, Angola, Malawi, and Zambia have suffered from a series of natural disasters that have been compounded by poor short-term policy decisionmaking in the past decade. Often policies are country specific while the effects of climate, pests, or trade span borders. In periods of severe crisis, such as the most recent drought, specific trade policies appear to be inappropriate to address issues of a regional dimension. It is therefore important to better understand both country-level agricultural policies and regional policies and their contribution to the mitigation of the food crisis that has emerged. The study is targeting four countries in the SADC region (Malawi, Mozambique, Tanzania, and Zambia).

11. ILRI (International Livestock Research Institute)

The International Livestock Research Institute (ILRI) works at the crossroads of livestock and poverty, bringing high-quality science and capacity-building to bear on poverty reduction and sustainable development.¹³

11.1 Current Research Areas

ILRI's implements climate change and related research in the following research areas:

- Targeting and System Change
- Animal Health and Genetic Resources
- Land Use and Natural Resources

11.2 Key Research Projects

11.2.1 Targeting and system change area

- *Crop-livestock productivity impacts of climate change*
Involves continental-scale analyses of likely changes in crop and biomass productivity under different scenarios of climate change to 2050 in Africa and Latin America, using high-resolution climate surfaces and crop and biomass models. The work is being expanded to cover several crops and forages, and outputs will help to identify geographic and thematic hotspots of change.
- *Mapping climate vulnerability and poverty in Africa*
Integrates the identification of likely hotspots of climate change in sub-Saharan Africa under different scenarios to 2050 with indicators of vulnerability. Many vulnerable regions are likely to be adversely affected, including the mixed arid-semiarid systems in the Sahel, arid-semiarid rangeland systems and the coastal regions of eastern Africa, and the drier zones of southern Africa. The work will be expanded in 2007-2008 to assist regional organisations provide IDRC's Climate Change Adaptation in Africa Research and Capacity Development Programme (CCAA) with targeting and impact assessment outputs, with a focus on linking scientific information with policy formulation and implementation. In 2007, DFID may support one or more higher-resolution country case studies for targeting and monitoring purposes.

¹³ For details, see <http://www.ilri.org/>.

- *Targeting and priority setting of climate change adaptation options*
This encompasses a study of the climate change adaptation options in the context of the ASARECA countries. This work intends to review the investment options and technological interventions proposed in the ASARECA Strategic Plan for sustained growth and poverty reduction in the region from a climate change perspective. It will examine them in terms of their potential susceptibility and risk to climate change impacts in order to draw a set of priority adaptation options for the different ASARECA recommendation domains. The work will be carried out in close collaboration with the ASARECA Networks and other CG Centres.
- *Livestock futures*
This encompasses several sets of activities:
Scenario analysis, building on existing work such as the Millennium Ecosystem Assessment, with a focus on impacts of different story lines on livestock sector development to 2030 and beyond;
Modelling work to derive meaningful projections of livestock numbers into the future, associated with changes in production system distribution, under a range of different scenarios; and
Studies that elucidate some of the key the natural resource impacts of the scenarios in terms of feed resource access and availability, methane emissions, and water use in livestock systems.
Outputs from this work will be used to help set priorities for ILRI and partners, and to suggest ways in which the research portfolio might be modified to help attain the goals of the institutions involved.
- *Climate change assessment tools*
In collaboration with CIAT and others, development and application of a system to generate characteristic daily weather data from downscaled, high-resolution climate surfaces, derived from several Global Circulation Models and SRES scenarios. Such a tool is an essential element in many priority-setting and impact-assessment activities related to climate change.
- *Trajectories of Change in Crop-Livestock Systems (TOC)*
Providing analytical tools to conduct systematic comparisons of crop-livestock systems and to predict changes in crop-livestock intensity and evolution in response to global drivers of change, including climate, built around a case-study in central Kenya. This work has provided information for several fora that have looked at possible future scenarios of agricultural development in Kenya.
- *Impacts of climate change in northern Kenya*
Livestock carrying capacities have been estimated in northern Kenya under a range of different climate change scenarios, using simple grassland and livestock productivity models, to assist VSF-Belgium in targeting and prioritising activities. Outputs from this work are informing

strategic decisions concerning the type of development assistance that may be needed in arid-semiarid pastoral systems in the coming years.

11.2.2 *Animal health and genetic resources*

- *Climate change and the implications for animal genetic resources*
A review study on the climate change and environmental degradation, and the policy implications on farm animal genetic resources in Africa, part of ILRI's contribution to the FAO-Wageningen exchange project.
- *Impacts of population and climate change on trypanosomiasis to 2050*
An Africa-wide study is currently looking at projected changes in the distribution of tsetse species to 2050, and how this may affect control strategies for different livestock systems. Broad-scale analyses have been completed. This work will continue through the GEF project in West Africa, to assess levels of zebu introgression into taurine populations (which is partly dependent on tsetse distributions), and to match livestock genotypes more closely with changing production systems and the environment.
- *Georeferencing of ILRI "Domestic Animal Genetic Information System" (DAGRIS).*
Livestock productivity and breed distribution information are currently being georeferenced for African cattle, sheep, and goats. This information overlaid with climatic and ecological GIS information will provide entry points for breed selection adapted to specific environmental parameters (e.g. drought tolerance).
- *Mapping of genetic diversity of indigenous livestock.*
Molecular characterisation studies are being done both at large geographical scale (continental studies) and in detail at the country level (such as sheep in Ethiopia), providing information on relationships between diversity and agroecological zones, in both quantitative and qualitative (uniqueness) terms. This work will provide baseline starting information on the effect of climatic change on livestock diversity.

11.2.3 *Land use and natural resources*

- *Climate-Land Interaction Project (CLIP)*
A collaboration between Michigan State University, ILRI, and others to understand the magnitude and nature of the interaction between land use and climate change at regional and local scales. These linkages are being examined through characterising and modelling agricultural systems, land use, the physical properties of land cover, and the regional climate in East Africa. Results include scenarios of climate change and effects on

productivity of mixed crop-livestock systems. CLIP will also assess the impacts of climate change on the distribution and composition of grass species in Kenya and their effect on grazers.

- *Country reports on adaptations to climate change*
Country reports are being developed on adaptations to climate change in Kenya, Uganda, and Tanzania. This work also falls under the CLIP project.
- *Land use and land cover dynamics and their interactions with regional climate in China*
China is undergoing rapid land-use changes related to economic growth, migration, land policy, and governmental projects such as tree planting, livestock projects, irrigation schemes, dams, and industrialisation. These changes are having a global impact on carbon, biodiversity, and other natural resources. Analyses are being conducted to determine past and current changes in land cover in western China to provide information on past and current linkages between land management and productivity, and to provide scenarios of the effect of future livestock management interventions on productivity. Results will be used for targeting and monitoring.
- *Trade-offs between carbon sequestration and farm income in smallholder agricultural systems in West Africa*
This study forms one component of the Soil Management CRSP project "Measuring and Assessing Soil Carbon Sequestration by Agricultural Systems in Developing Countries," led by the University of Florida. This study assesses the income-generating and carbon-sequestration potential of different crop and livestock management strategies. Results of the study will provide information on the prospect of smallholders' participation in payment schemes under the Clean Development Mechanism of the Kyoto protocol as well as household modelling tools that can be used in other assessments of climate change impacts in different places.

11.3. Research Plans

ILRI is already reaching out to development and research partners in both developing and developed countries to implement activities aimed at addressing knowledge gaps; additional, specific work in the areas of animal genetic resources, animal health, and animal nutrition will complement ongoing targeting and impact assessment activities in 2007 and beyond.

12. IRRI (International Rice Research Institute)

IRRI is a non-profit research and training centre established to reduce poverty and hunger, improve the health of rice farmers and consumers, and ensure environmental sustainability through collaborative research, partnerships, and strengthening of national agricultural research and extension systems.¹⁴

12.1 Current Research Areas

IRRI implements climate change and related research in the following areas:

- Social Sciences and GIS
- Crop Physiology and Genetics
- Soil, water and systems management/ Greenhouse Gas Emissions
- Climate Studies

IRRI is also the convening institution for the Rice and Climate Change Consortium.

12.2 Key Research Projects

12.2.1 Social sciences and GIS

- Assessing impact of climate change on farmers' crop management decisions in Bangladesh
- Analysing longitudinal data on crop production Asia to estimate the effect of climate variation on productivity
- Developing high resolution climate surfaces of current climate and downscale model predictions of future climate (<http://www.worldclim.org>)
Using these data together with simulation models to:
 - Assess the impact of climate change on global rice production
 - Assess the potential impact of technology and other mitigation options to respond to future climate change
 - Study threats to the conservation of wild crop relatives under climate change
- Studying effect of sea level rise on the flooding regimes and salinity intrusion in Vietnamese Mekong Delta and its implications for rice production

¹⁴ <http://www.irri.org/>.

12.2.2 Crop physiology and genetics

- Estimating rice yield declines with higher night temperature from global warming
- Studying genetic variation of grain yield in response to warm night-time temperature
- Examining phenotypic plasticity of the rice crop from early tillering to heading: impact of low radiation on assimilate partitioning and crop performance (managing projected increases in cloud cover)
- Examining response of the genotype variability to increasing temperatures: impact of a range in cropping periods on rates of leaf emergence and leaf elongation and on crop performance
- Searching for wild species and derivatives possessing early morning anthesis to avoid heat induced sterility under warming climate scenarios
- Determining genetic variation in time of day for rice flower opening
- Impact of heat and drought on gene expression in rice flowers and the consequences for yield
- Screening rice genotypes for high temperature and salinity tolerance to cope with increasing temperatures and sea water intrusion

12.2.3 Soil, water and systems management/ greenhouse gas emissions

- Studying the potential of rice residues as soil amendment in carbon sequestration, in order to reduce green house gas emissions
- Quest for Healthy Redox Potential: Determining the appropriate depth gradients for flooded rice soils in order to minimise greenhouse gas emissions
- Evaluating existing water-saving irrigation techniques
- Developing a rice-cropping system with high water productivity and low environmental impact by integrating water-saving techniques; soil, fertiliser, crop management; and newly developed breeding materials
- Monitoring nitrous oxide and methane emissions under alternate wetting and drying water saving conditions (ongoing)
- Reducing vulnerability of rice-based agroecosystems in Asia to changes in pest scenarios induced by climate change
- Accounting for methane emissions of different crop management techniques (1991-1995, funded by US-EPA)
- Assessing the impact of rice cultivars on methane emissions (1995-1998, funded by GTZ)
- Developing interregional program on methane emissions from different rice ecosystems in China, India, Thailand, Indonesia and the Philippines (funded by UNDP/GEF; 1993-1999)
- Conducting process-based studies on soil/ plant interaction in regulating methane emissions (1995-2000)
- Studying nitrous oxide emissions affected by different water management and nitrogen applications (1995-1998)

- Measuring effect of plant residue management (quantity, quality and timing) on greenhouse gas emissions in the field
- Studying theoretical aspects of temperature, yield, and climate change, resulting in a simple climate change model for rice

12.2.4 Climate studies

The Climate Unit is currently engaged in numerous activities related to climate change, such as:

- Conducting regular weather monitoring over several decades at various sites of the Philippines ,
- monitoring atmospheric background concentration of ozone, nitrous oxide, and sulfur dioxide and acidity in rainfall
- recording crop phenology, including time of day of flowering
- assessing frequency, intensity, and impacts of weather extremes in the Philippines
- modelling and mapping present and future rice yields for 25 sites in the Philippines based on empirical weather data and GCM outputs (obtained from U.K Hadley Centre), respectively

13. IWMI (International Water Management Institute)

The International Water Management Institute focuses on the sustainable use of water and land resources in agriculture and on the water needs of developing countries. IWMI works with partners in the South to develop tools and methods to help these countries eradicate poverty through more effective management of their water and land resources.¹⁵

13.1 Current Research Areas

The main premise and overall framework for climate change related research work at IWMI has been that by better understanding and adapting to existing climate variability, society will be better equipped to withstand its adverse consequences.

IWMI has contributed directly and indirectly to several international assessments on water, food, and the environment that take into account climate variability and change impacts (e.g. Comprehensive Assessment of Water Management in Agriculture, Millennium Ecosystem Assessment, International Assessment of Agricultural Science and Technology for Development, and Global Environment Outlook). IWMI researchers have participated as expert reviewers of the IPCC's Fourth Assessment Report. IWMI is one of three CGIAR centres, along with ICRAF and CIFOR, accredited with the UNFCCC, and as such can participate in the annual Conference of the Parties as an Intergovernmental Organisation (IGO).

IWMI leads the "Integrated Basin Water Management Systems" theme of the Challenge Program on Water and Food. The theme's research agenda focuses on how basin water and land resources could be better managed to enhance agricultural output, productivity, and profitability in a sustainable way. Issues on climate variability, climate change, and adaptation addressed by the theme include: understanding climate variability (particularly floods and droughts), assessing vulnerability of the poor to these extreme events, and identifying coping strategies.

IWMI developed World Water and Climate Atlas, which provides information on climate and moisture availability for agriculture and is of direct relevance to climate change researchers, planners, and those carrying out adaptation activities. IWMI also leads the CGIAR Consortium for Spatial Information (CSI), which provides framework data for global spatial analysis and modelling conducted by various CGIAR centres. The CSI activities include, among many others, the development of a spatial database of climate change scenarios, which aims to promote and support climate change analysis by a broader scientific community.

¹⁵ <http://www.iwmi.cgiar.org/>.

13.1.1 Drought assessment and mitigation

A large portion of research at IWMI focuses on drought assessment and mitigation. Drought is a major issue for developing countries that rely on rainfed agriculture. There are two ways of addressing drought; 'drought response' (reactive approach, focusing primarily on drought relief after drought has occurred) and drought mitigation (pro-active approach, whereby anti-drought actions are taken in advance). The reactive approach is still the dominant one in most developing countries. If not changed, this will adversely affect the ability of many developing countries in the region to adapt to climate change.

13.1.2 Adaptation strategies

Examination of various adaptation strategies to climate change in various regions

13.1.3 Global modelling tools for scenario analysis

IWMI has developed a global model (WATERSIM) to analyse various scenarios of the food-water-environment nexus. The model is based on water accounting, fully integrates water and food modules, uses a combination of hydrological and administrative boundaries, and allows the following issues of global change and adaptation to it to be examined:

- trade-offs between irrigated and rain-fed agriculture in food production
- impacts of international agreements on trade and water use at regional and basin levels
- impacts of alternative investment strategies on water infrastructure and agriculture
- impacts of environmental regulations on agricultural production
- impacts of rainfall and water resources variability on food production

Capacity is also available at IWMI to analyse both hydrological and atmospheric components for basin water management, derive local climate scenarios from meso-scale climate models, and use them to assess impacts of land-use change on climate

13.1.4 Climate change and water policy

A variety of studies is ongoing (see below).

13.1.5 Climate change mitigation analysis

Global and local datasets are used to simulate CDM-related changes in land-use and farming systems and their consequences for local communities and overall food security. A similar modelling approach is applied to examine regional and basin-wide water use impacts associated with climate change.

13.2 Key Research Projects

13.2.1 Drought assessment and mitigation

This recently completed project in South-West Asia aimed to identify the technical, institutional, and policy gaps that existed in drought research and management in three countries in the region (India, Pakistan, and Afghanistan); enhance regional cooperation in drought management; and suggest recommendations for effective drought mitigation in the mentioned countries. The project addressed a variety of technical and social issues, including developing a remote-sensing data-based, regional drought-monitoring system; analysis of drought frequency and magnitude using precipitation time series; drought analyses software development; socioeconomic surveys of rural population; review and analysis of drought-related institutions and policies; and review / assessment of the potential of water harvesting technologies to withstand droughts. The project was carried out in collaboration with a number of local research institutes and NGOs.

Current drought research activities at IWMI include quantification of drought risks and low flows in Iran; climate change-induced impacts on irrigation schemes in Morocco; and global mapping of drought-related indicators that reflect various aspects of drought— from drought hazard and vulnerability of water resources systems to drought to indicators of drought preparedness, etc. Attempts are being made to initiate drought-research projects in East and West Africa. The details of IWMI drought work are available at the IWMI Drought Information Centre web site (<http://www.iwmi.cgiar.org/drw/>), which also contains information on drought research in other CGIAR centres.

13.2.2 Adaptation strategies

An example of research that directly examined the various adaptation strategies to climate change in various regions is the ADAPT project “Water, Climate, Food, and Environment under Climate Change: An Assessment of Global and Regional Impacts and the formulation of Adaptation Strategies for River Basins.” ADAPT included studies in seven contrasting river basins: Rhine (Western Europe), Sacramento (USA), Syr Darya (Central Asia), Volta (Ghana), Mekong (Southeast Asia), Walawe (Sri Lanka), and Zayandeh (Iran), where GCM predictions were downscaled to river basins for hydrological modelling in order to compare different response strategies for protecting the environment, improving food production, and enhancing industrial capacity. IWMI coordinated the study, simulated adaptation strategies to sustain food security in all study basins, and carried out full studies in Sri Lanka, Iran, and Mekong. IWMI is currently working with the Mekong River Commission (MRC) to incorporate IPCC climate change scenarios into the MRC development scenarios and analyse impacts on the Mekong river flow.

13.2.3 Global modelling tools for scenario analysis

A study has been recently completed for the Sudd case in the Upper Nile, and an analysis of impacts of climate change on land use is ongoing.

13.2.4 Climate change and water policy

An ongoing study analyses, for the first time, the multiple transboundary water treaties and examines a range of mechanisms that mitigate the negative impacts of changes in transboundary water availability associated with climate variability and change. The study considers strategies in transboundary water law formation that are both politically feasible and can mitigate the impacts of variability on riparian relations. Studies suggest that climate change impacts will be most significant in Africa. Therefore, it is important to make water resource variability an integral part of the transboundary water management (e.g. in the Nile basin).

Another current project examines the links between malaria incidence and climate variables in Sri Lanka. It aims to develop an early warning tool that may be able to predict the impacts of climate change on malaria hazards. IWMI also leads a System-wide Initiative on Malaria and Agriculture (SIMA), which aims to increase the understanding of links between malaria and agriculture, and to test innovative interventions for malaria control under different agricultural systems and, potentially, climate change scenarios.

Several ongoing projects focusing on wetland assessment and management, are developing research on adaptation to climate change through the medium of water. Researchers are examining it from both an environmental and food production perspective, aiming to find adaptation mechanisms that do not entail a conflict between the two. Part of the ongoing research focuses on how changes in ecosystems as a consequence of CC compound existing feedbacks (such as spread of invasive species or water quality changes) on agriculture and potentially constrain local and institutional adaptation.

IWMI is also involved in research related to the field of environmental flow assessment and management at different scales—from global to river basins. Research on environmental flows address issues such as how to allocate water under climate variability for *multiple* purposes and to assess effectiveness in terms of the provision of wider ecosystem services, including food. Some of the ongoing projects (such as those in the Mekong tributaries and the Volta Basin) examine the assimilation of environmental flows into future basin water allocation models under climate change scenarios.

13.2.5 Climate change mitigation analysis

Ongoing research examines some implicit hydrologic dimensions of international efforts to mitigate climate change, like those of the Clean Development Mechanism (CDM)— "carbon sink" provisions of the UNFCCC's Kyoto Protocol— on global, regional, and local water cycles. The main mitigation measures studied are the conversion of large land areas to forestry, and the redistribution of water use (through increased evaporation, reduced runoff, etc.). Global and local datasets are used to simulate CDM-related changes in land-use and farming systems and their consequences for local communities and overall food security. A similar modelling approach is applied to examining regional and basin-wide water-use impacts associated with climate change. GCM scenario climate variables are used as inputs, and both the implications of CDM carbon sink projects under changing climatic conditions, and land-use changes in general, are examined. Potential water scarcity hotspots are thus being identified under combinations of land-use change and climate change.

14. World Agro-Forestry Centre (ICRAF)

The World Agro-Forestry Centre is dedicated to advancing the science and practice of agroforestry to transform the lives and landscapes of the rural poor in developing countries.¹⁶

14.1. Current Research Areas

The World Agro-Forestry Centre's climate change research is based on many partnerships:

- ICRAF scientists have been active in the activities of the IPCC for the past decade. Recently two scientists participated in the revision of the National Greenhouse Gas Accounting Guidelines. One scientist is serving as coordinating lead author of the IPCC 4th Assessment Report (AR4).
- ICRAF has been collaborating with UNEP, IUCN, and FAO to provide technical support to climate change negotiators from Africa and Latin America. Its input was most intense during the negotiations over the modalities for afforestation and reforestation as part of the Clean Development Mechanism. Support continues on a much less intensive level.
- ICRAF has coordinated the Inter-Centre Working Group of the CGIAR since its inception in 1998 until earlier this year.
- ICRAF co-organised the South Asia Expert Workshop on Climate Change and Agriculture in the lead-up to COP 8 in Delhi.

Together with its partners, it focuses on two key research areas:

14.1.1 Carbon sequestration in agroforestry systems

Climate change research at ICRAF began with the Alternatives to Slash and Burn (ASB) Program, hosted by the Centre. Work within the ASB program focused primarily on quantifying carbon stocks in tropical forests and alternative land use systems, quantifying the effect of land use change on biosphere-atmosphere exchange of trace gases and quantifying the tradeoffs between private benefits to farmers and global environmental benefits.

In the late 1990s, there was much interest in the possibility for agroforestry to contribute to climate change mitigation. ICRAF began looking for synergies between sustainable agroforestry systems and carbon sequestration. A number

¹⁶ <http://www.worldagro-forestrycentre.org/>.

of projects in different systems continue to quantify the carbon benefits of improved agroforestry practices.

With the Kyoto Protocol entering into force, and with the development of the voluntary carbon offset market, ICRAF has expanded this work over the past several years and is working at the landscape scale to facilitate carbon sequestration projects in smallholder communities, building on the earlier work of quantification of the carbon sequestration potential of different agroforestry practices. The research has several components:

- Developing measurement and monitoring tools
- Developing other tools for project developers
- Understanding institutional issues to facilitate carbon trading
- Developing knowledge of how synergistic effects between carbon sequestration and sustainable land management can be generated through agroforestry systems.

14.1.2 Adaptation to climate change

ICRAF is also working on adaptation to climate change at several levels. At the level of individual tree species, ICRAF has been working to understand the phenology of flowering and fruit production and how climate affects this phenology. This is a relatively new area for ICRAF, and activities have been ongoing for only a short period.

At the systems level, ICRAF has been working on understanding the mechanisms by which improved systems buffer against interannual climate variability, with a focus on improving fallows in East and Southern Africa.

At the regional scale, ICRAF is leading a consortium that specifically studies adaptation to climate change. Several nascent projects have been funded and are operational. In Southeast Asia, ICRAF has done some work on water balances, linking regional water balance models to land use scenarios and is currently exploring landslide risks as a result of climate change and land-use change.

ICRAF has conducted three assessments of the state of knowledge within the agricultural research community in Sub-Saharan Africa to facilitate adaptation to climate change.

14.2 Key Research Projects

14.2.1 Carbon sequestration in agroforestry systems

- Developing measurement and monitoring tools to:

- Assess carbon in landscapes and determine changes in carbon stocks
 - Assess the development and livelihoods benefits of carbon sequestration projects
 - Assess non-CO₂ greenhouse gas fluxes between soils and atmosphere in different land management systems
- Developing other tools for project developers
 - Land suitability modelling (in collaboration with IWMI)
 - Socioeconomic assessment tools
 - Tools for preliminary studies required for developing a CDM Project Design Document
- Understanding institutional issues to facilitate carbon trading
 - Local level tree growers groups
 - National level (Designated National Authorities)
 - International level—linkages between smallholder farming communities and the carbon market.
- Developing knowledge of how synergistic effects between carbon sequestration and sustainable land management can be generated through agroforestry systems.
 - Quantifying the mechanisms by which agroforestry systems reduce climate related stress.
 - Determine the net greenhouse balance of different agroforestry systems.

15. WorldFish Centre

The WorldFish Centre aims to reduce poverty and hunger by improving fisheries and aquaculture.¹⁷

15.1 Current Research Areas

Research areas related to climate change focus on

- Coral Reef Management
- Coral Bleaching
- Small-Scale Fisheries, and
- Water Management

15.2 Key Research Projects

15.2.1 *Coral reef management.*

- The GEF-funded project “Lessons Learned and Best Practices in Coral Reef Management” is formalising the experiences and lessons learned from more than 75 previous and current GEF projects, as well as major non-GEF initiatives, involving coral reefs and associated ecosystems. This includes an emphasis on adaptation to climate change. The project will seek to identify what has worked and what could be improved upon in supporting biodiversity conservation within the broader context of climate change.

15.2.2 *Coral bleaching.*

- Temperature-driven coral bleaching is now considered to be one of the most significant and widespread threats to coral reefs. Working with the International Coral Reef Assessment Network, the Centre’s Global Information System for Coral Reefs (ReefBase) serves as the global repository for records of coral bleaching. The Centre has also recently developed a global protocol for monitoring of coral bleaching that enables researchers to collect standardised, quantitative data on this phenomenon. Further data management tools are being developed to ensure that environmental and biological data and results are collected and shared among all researchers, managers, and policymakers.

15.2.3 *Small scale fisheries.*

- WorldFish is developing and testing new conceptual frameworks for the management of small-scale fisheries. Most of the world’s fishers live in developing countries and work in small-scale fisheries. Climate change represents a potentially overwhelming source of external shock to these fishery-dependent communities, and building adaptive capacity to such

¹⁷ For more details, see: <http://www.worldfishCentre.org/cms/default.aspx>.

shocks will become an increasingly dominant objective of fisheries management. This work is being done in Sub-Saharan Africa, Indonesia, the Solomon Islands, and in the lower Mekong basin.

15.2.4 Water management

- The Centre is engaged in a series of research projects that seek to improve water management in fish farming systems, including the implications of intensification of production on food-associated water use and water poverty. The Centre is also developing tools to optimise water use in fisheries and aquaculture during water scarcity, and tools that will assist in considering fisheries in trade-offs in water allocation.

15.3 Research Plans

15.3.1 Improving global and regional assessments of fisheries vulnerability to climate change

In-depth analyses of vulnerability to climate change are needed to improve understanding and awareness of the impact of climate change on fishery-dependent communities and to better target future national and international mitigation investments. These analyses need to combine assessments of the risk that different ecosystems will be impacted by climate change, and the capacity of the fisheries and their dependent communities to adapt to any such impacts. To achieve this future research should focus upon:

- Development of quantitative vulnerability indices and metrics to predict, monitor, and evaluate impacts on both ecosystems and those who depend upon them;
- Generation of maps and other spatially resolved analyses of fisheries vulnerability to climate change, focusing on those systems where vulnerability is highest—notably river basins, lakes, and inshore coastal fisheries;
- Development of scenarios for different climate-change projections and variable impacts on fisheries, including measures being taken to mitigate the impacts of climate change such as water harvesting and infrastructure development.

Outputs will include: 1) Global and regional maps of fisheries hot spots guiding investment in mitigation and adaptation; 2) Measures of relative risk in diverse fishing systems in inland and coastal environments; and 3) Raised awareness and understanding of where vulnerability to climate change is greatest

15.3.2 Development and application of fisheries management systems that build adaptive capacity and resilience in fisheries dependent communities.

Current fisheries management practice does not place sufficient emphasis on the opportunities and threats that arise from exogenous threats. Climate change will create uncertainties in this sector and hence new management systems must be developed that place a greater emphasis on building adaptive capacity. Such a strategy should integrate ecological and social drivers. To achieve this, future research should focus upon:

- Development of management concepts and approaches that provide incentives to both mitigate risk and adapt under changing scenarios, particularly including external shocks;
- Detailed analysis of how fishing communities respond to change and to increased uncertainty and risk as a result of external factors such as climate change.

This research should focus on fishery systems that have already been identified as being of highest risk to climate change, including coral reef fisheries that are especially vulnerable to sea level rise and bleaching; other climate sensitive coastal fisheries in West Africa, South and Southeast Asia, and the Small Island Developing States of the Pacific and Caribbean; and inland fisheries in both river and lake systems.

Outputs will include: 1) Tools for managing fisheries in the face of climate change, and 2) Increased capacity to apply these tools and approaches and sustain fisheries in the face of climate change.

15.3.3 Assessment of future scenarios for aquaculture development.

Aquaculture is increasingly recognised as providing an important mechanism for diversifying and improving the productivity of farming systems in many regions, especially in Africa and Asia. Climate change brings the prospect of increasing the potential for aquaculture in some regions and diminishing it in others. In response to this uncertainty, future research should focus upon:

- Spatial analyses of agroecosystems where opportunities for aquaculture will diminish, and those where it will increase, under different climate change scenarios;
- Identification of the risks and opportunities facing aquaculture as a result of climate change, including increased prevalence of disease, changes in availability of fishmeal and fish oil for fish feed, increased incentive for diversifying farming systems in increasingly drought prone systems;
- Identification of opportunities for the development and expansion of new technologies for aquaculture, including new species and improved strains;

- Identification of role of aquaculture in sustaining food production systems and livelihoods.

Outputs will include identifying: 1) High-opportunity areas for aquaculture development, 2) New technologies needs required to exploit this potential, 3) Areas where climate change will increase the risks for sustainable aquaculture development, and 4) Climate-change mitigation strategies, including technology development priorities.

15.3.4 Development of improved aquaculture technologies for resilient livelihoods.

Where climate change will constrain the potential of aquaculture technologies, innovation solutions may be found through technology innovation. Similarly where climate change opens up the possibility of new opportunities for aquaculture, new technologies may be needed to seize these opportunities. To support the development of these technologies, future research should focus upon:

- Identification of new candidate species for aquaculture that are adapted to future conditions and developing methods for managing these in farmed conditions;
- Development of new strains of fish that are better adapted to conditions brought about through climate change, notably increased temperature, salinity, and risk of disease;
- Development of technologies for managing the increased incidence of disease that is likely in fish farms under conditions of increased temperature;
- Development of innovative integrated farming systems where pond aquaculture increases diversity of farming options and resilience to drought;
- Integration of fish farming into farming systems that use low-quality water and/or saline water.

This research should focus on those areas that have already been identified as providing the greatest opportunities, and/or being exposed to the highest risk, under climate change. This is likely to include Sub-Saharan Africa, Bangladesh and India, and western China.

Outputs will include: 1) New species introduced into fish farming systems adapted for new climate conditions, 2) Disease-management technologies, 3) Integrated aquaculture-agriculture systems that increase resilience in the face of climate change, and 4) Technologies that will enable farming fish in conditions of low water quality