CCAFS Report no. 1

CGIAR Challenge Program on Climate Change, Agriculture and Food Security

CLIMATE CHANGE
AGRICULTURE AND FOOD SECURITY

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CGIAR Challenge Program on Climate Change, Agriculture and Food Security

prepared by

the CGIAR Alliance, the Earth System Science Partnership and their respective partners

in collaboration with

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and in consultation with

FAO and WFP

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Front cover photo: Ethiopia, Amhara Region – A farmer irrigates his field of potatoes with the help of the Lake Tana Watershed project. IFAD (International Fund for Agricultural Development) are currently involved in the Lake Tana Watershed project, which focuses on mitigating and adapting to climate change. © Petterik Wiggers, Panos Pictures

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Acronyms and abbreviations

ACMAD . . . . . .African Centre of Meteorological Application for Development
Aghrymet . . . . . .A regional centre of CILSS concerned with the collection and distribution of information that relates to food security and water management in the nine CILSS countries
AGM . . . . . .Annual General Meeting (CGIAR)
AGROPOLIS . . . . . .Umbrella organisation of several agricultural research institutes in France
AIACC . . . . . .Assessments of Impacts and Adaptations to Climate Change in Multiple Regions and Sectors (START)
AIMES . . . . . .Analysis, Integration and Modelling of the Earth System (IGBP)
AMMA . . . . . .African Monsoon Multidisciplinary Analysis (WCRP-GEWEX)
APN . . . . . .Asia-Pacific Network for Global Change Research
AR4 . . . . . .Fourth Assessment of the Intergovernmental Panel on Climate Change
ARI . . . . . .Advanced Research Institute
ASARECA . . . . . .Association for Strengthening Agricultural Research in Eastern and Central Africa
AU . . . . . .African Union
CAS-IP . . . . . .Central Advisory Service on Intellectual Property
CCAFS . . . . . .Challenge Program on Climate Change, Agriculture and Food Security (CGIAR-ESSP)
CGIAR . . . . . .Consultative Group on International Agricultural Research
CIAT . . . . . .International Center for Tropical Agriculture (CGIAR)
CILSS . . . . . .Comité inter-Etats de lutte contre la sècheresse au Sahel
CLIVAR . . . . . .Climate Variability and Predictability (WCRP)
COMESA . . . . . .Common Market for Eastern and Southern Africa
CORAF/WECARD . .Conseil ouest et centre Africaine pour la recherche et le développement agricole/West and Central African Council for Agricultural Research and Development
CP . . . . . .Challenge Program (CGIAR)
C/P WG . . . . . .Working Group of CLIVAR
CRM . . . . . .Climate Risk Management
DIVERSITAS . . . . . .An International Programme on Biodiversity Science (ICSU, UNESCO, IUBS, SCOPE)
ESSP . . . . . .Earth System Science Partnership (DIVERSITAS, IGBP, IHDP, WCRP)
FAO . . . . . .Food and Agriculture Organization of the UN
FARA . . . . . .Forum for Agricultural Research in Africa
GCM . . . . . .Global Climate Model
GCP . . . . . .Generation Challenge Program
GEC . . . . . .Global Environmental Change
GECAFS . . . . . .Global Environmental Change and Food Systems (ESSP)
GECHS . . . . . .Global Environmental Change and Human Security (IHDP)
GEDIT . . . . . .Geospatial Diagnostic Toolkit (CCAFS)
GEWEX . . . . . .Global Energy and Water Cycle Experiment (WCRP)
GHG . . . . . .Greenhouse gases
GLASS . . . . . .GEWEX Land-Atmosphere Systems Study
GLP . . . . . .Global Land Project (IGBP, IHDP)
GSOP . . . . . .Global Synthesis and Observations Panel (WCRP-CLIVAR)
GWSP . . . . . .Global Water System Project (ESSP)
HAP . . . . . .Hydrologic Applications Projects (WCRP-GEWEX)
IAI . . . . . .Inter-American Institute for Global Change Research
ICPAC . . . . . .IGAD Climate Prediction and Applications Centre
ICSU . . . . . .International Council for Science
IFPRI . . . . . .International Food Policy Research Institute (CGIAR)
IGAD . . . . . .Intergovernmental Authority on Development in Eastern Africa
IGBP . . . . . .International Geosphere-Biosphere Programme (ICSU)
IGFA . . . . . .International Group of Funding Agencies for Global Change Research
IGP . . . . . .Indo-Gangetic Plain
IHDP . . . . . .International Human Dimensions Programme on Global Environmental Change (ICSU, ISSC, UNU)
ILRI . . . . . .International Livestock Research Institute (CGIAR)
INRM . . . . . .Integrated Natural Resource Management
IOC . . . . . .Intergovernmental Oceanographic Commission (UNESCO)
IP . . . . . .Intellectual Property
IPCC . . . . . .Intergovernmental Panel on Climate Change (UNEP, WMO)
IPG . . . . . .International public goods
IRI . . . . . .International Research Institute for Climate and Society
IRRI . . . . . .International Rice Research Institute (CGIAR)
ISSC . . . . . .International Social Science Council
IT . . . . . .Industrial Transformation (IHDP)
IUBS . . . . . .International Union of Biological Sciences (ICSU)
MAHASRI . . . . . .GEWEX
MDG . . . . . .UN Millennium Development Goals
NARES . . . . . .National agricultural research and extension institutes
NARS . . . . . .National agricultural research systems
NGO . . . . . .Non-governmental organisation
NRM . . . . . .Natural resources management
OASIS . . . . . .Global agricultural research for development against dryland degradation and desertification
PAGES . . . . . .Past Global Changes (IGBP)
PIK . . . . . .Potsdam Institute for Climate Impacts Research
RCM . . . . . .Regional Climate Models
REDD . . . . . .United Nations Collaborative Program on Reducing Emissions from Deforestation and Forest Degradation in Developing Countries
RPG . . . . . .Regional public goods
RWC . . . . . .Rice–Wheat Consortium (CGIAR)
SADC/FANR . . . . . .Southern African Development Community - Food, Agriculture and Natural Resources Directorate
SCOPE . . . . . .Scientific Committee on Problems of the Environment (ICSU)
SRO . . . . . .Sub-Regional Organisations; ASARECA, CORAF/WECARD, SADC/FANR
START . . . . . .Global Change SysTem for Analysis, Research and Training (ESSP)
TFSP . . . . . .Task Force on Seasonal Prediction (WCRP)
TPE . . . . . .Target Populations of Environments
UGEC . . . . . .Urbanization and Global Environmental Change (IHDP)
UNESCO . . . . . .United Nations Educational, Scientific and Cultural Organization
UNFCCC . . . . . .United Nations Framework Convention on Climate Change
UNU . . . . . .United Nations University
VACS . . . . . .Variability of the African Climate System (WCRP-CLIVAR)
WCRP . . . . . .World Climate Research Programme (WMO, ICSU, IOC)
WFP . . . . . .World Food Program
WGCM . . . . . .Working Group on Coupled Models (WCRP-CLIVAR)
WGNE . . . . . .Working Group on Numerical Experimentation (WCRP)
WGSIP . . . . . .Working Group on Seasonal to Interannual Variability (WCRP-CLIVAR)
WMO . . . . . .World Meteorological Organization

Preface

A CGIAR Challenge Program (CP) is a time-bound, independently-governed programme of high-impact research that targets the CGIAR goals in relation to complex issues of overwhelming global and/or regional significance, and requires partnerships among a wide range of institutions in order to deliver its products.

Exploratory discussions in 2007 between representatives from all 15 CGIAR Centers and leading researchers from the global environmental change research community, under the auspices of the Earth System Science Partnership (ESSP), agreed to jointly prepare a proposal for a Challenge Program on issues relating to agriculture, food security and climate change. Following a detailed scoping exercise, which culminated in a successful pre-proposal for a CP, this document was prepared by a Leadership Group comprising four CGIAR and four ESSP representatives (Annex 1).

This final version of the Program is based on the version agreed by the Chair of the Alliance Executive and the Chair of the ESSP Scientific Committee and incorporates early comments by the CGIAR Science Council and Executive Council. It was approved by the CGIAR Executive Council (May 2008) subject to CGIAR Science Council agreement of revisions (agreed September 2008).

The Alliance of the CGIAR Centers and ESSP are very grateful to the many people who have made contributions to its development, including those in the various planning and drafting workshops, and those who have contributed electronically.

Summary

The Challenge Program on Climate Change, Agriculture and Food Security (CCAFS) unites the complementary strengths of the CGIAR system and the Earth System Science Partnership (ESSP), and their respective partners, to address the most pressing and complex challenge to food security in the 21st century. It is a response to accumulating evidence that the food security and livelihoods of hundreds of millions of people who depend on small-scale agriculture are under significant threat from climate change.

The goal of CCAFS is to overcome the additional threats posed by a changing climate on attaining food security, enhancing livelihoods and improving environmental management. CCAFS will address this goal by generating the knowledge base and toolsets to enable and assist farmers, policymakers, researchers and donors to successfully manage agricultural and food systems so as to strengthen food security, enhance rural livelihoods, and improve environmental sustainability in the context of the challenges arising from current climate variability and progressive climate change.

CCAFS's objectives are: (1) to close critical gaps in knowledge of how to enhance – and manage the tradeoffs between – food security, livelihood and environmental goals in the face of a changing climate; (2) to develop and evaluate options for adapting to a changing climate to inform agricultural development, food security policy and donor investment strategies; and (3) to assist farmers, policymakers, researchers and donors to continually monitor, assess and adjust their actions in response to a changing climate.

The research is structured within six Themes. The first three – 'Diagnosing vulnerability and analysing opportunities', 'Unlocking the potential of macro-level policies' and 'Enhancing engagement and communication for decision-making' – provide an analytical and diagnostic framework for CCAFS that is grounded in the macro-policy environment, and ensures effective engagement of rural communities and institutional and policy stakeholders. The second three – 'Adaptation pathways based on managing current climate risk', 'Adaptation pathways under progressive climate change' and 'Poverty alleviation through climate change mitigation' – will develop and evaluate instruments, technologies, practices and partnerships needed to decrease the vulnerability of food systems and enable them to prosper under a variable and changing climate. These Themes will also identify and prioritise institutional and policy options for overcoming obstacles to implementing these strategies. The research will produce international public goods (IPG) that will help protect and enhance progress toward achieving sustainable food security and poverty reduction in developing countries in the face of new and intensified challenges imposed by a changing climate.

The strategic alliance between the CGIAR and the ESSP, and their respective partners, will bring together the world's best researchers in agricultural science and Earth system science. CCAFS will build on and amplify both the CGIAR and the ESSP core research agendas, adding value to each and elevating their relevancy to policymakers and stakeholders. The collaboration will allow a truly integrated multi-disciplinary, resilience-based approach to the climate change–food security problem.

Research will be implemented jointly through CGIAR and ESSP partners, other relevant advanced research institutes (ARIs), relevant regional institutions and organisations, and appropriate national institutions (e.g. national agricultural research and extension services, meteorological services and universities). Theme Leaders will be responsible for designing and initiating research activities within their Themes, and for ensuring that work is integrated across questions and among Themes. Much of the research is inherently place-based and will be carried out in focus regions that have populations and agriculture vulnerable to

climate change, sufficient institutional capacity and offer a high chance of generating transferable results. The outputs will be IPG with utility well beyond the research locations. The three regions selected for initial research are the Indo-Gangetic Plains, Eastern Africa and Western Africa; others may be added as funding allows. Research within focus regions will target spatial levels ranging from field to sub-regions. Where possible and appropriate, it will build on ongoing CGIAR and national research infrastructure and research sites.

The activities and outputs of CCAFS are orientated towards three high-level outcomes to achieve impact:

1. Climate variability and climate change issues mainstreamed into national, regional and international agricultural development strategies and institutional agendas.
2. Innovative information products and communication processes developed and maintained at local, national and regional levels.
3. Effective, climate-informed decisions made relating to: (a) setting priorities to identify and fund research and development agendas and adaptation policies and investments at international and regional levels; (b) promoting and implementing adaptation options that render rural communities better able to monitor and adapt to climate variability and change, with full knowledge of the tradeoffs that arise between multiple objectives of increasing food security and sustaining livelihoods and the environment; (c) establishing and maintaining a supporting institutional, policy and infrastructural environment so that adaptation options are effective.

CCAFS has a 10-year timeline:

- Phase 1 (years 1–5): detailed scoping; establishing research teams; building stakeholder communities; reviewing existing preliminary studies; developing initial methodologies; establishing baselines through analyses of current impacts and vulnerabilities; undertaking *ex-ante* assessments of anticipated changes due to CCAFS activities; commissioning initial research on adaptation and mitigation pathways; initial dialogue with the policy community and non-research communities; and delivering a detailed work plan for Phase 2.
- Phase 2 (years 6–10): undertaking detailed analyses of adaptation and mitigation pathways; identifying areas of potential benefits from climate change; capacity building for undertaking trade-off analyses and identifying win–win situations; undertaking *ex-post* analyses of performance of CCAFS activities; launching research into additional and/or emerging issues; ensuring capacity is in place to continue research after the end of the Program; and enriching the dialogue with the policy community and non-research communities.

An independent Steering Committee, comprising a Chair and about 8-10 members, will oversee and make decisions on science direction and resource allocation. Non-voting CGIAR Alliance and ESSP representatives will maintain links to their respective agendas. The CCAFS Director, the six Theme Leaders and a representative from the institution which hosts the Director and the Secretariat of CCAFS form the CCAFS Management Team. A Stakeholder Advisory Platform will provide advice from stakeholders and maintain their buy-in. This will be open to all interested parties, and funds will be provided to ensure representation from key agencies and stakeholder groups.

CCAFS anticipates a ramped funding level from about US$10 million in the first year to US$25 million per year for year 5. Phase 2 funding will be laid out in the detailed work plan to be delivered at the mid-term review.

The CCAFS start-up phase has now been initiated and members of the CCAFS Steering Committee appointed (Annex 2). A search for Director and host institution for the Secretariat has recently been completed. An international Launch Conference is anticipated in early 2010.

1. The Challenge

1.1. Introduction

Climate change represents an immediate and unprecedented threat to the food security of hundreds of millions of people who depend on small-scale agriculture for their livelihoods. At the same time, agriculture and related activities also contribute to climate change, by intensifying greenhouse gas (GHG) emission and altering the land surface. Responses aimed at adapting to climate change may have negative consequences for food security, just as measures taken to increase food security may exacerbate climate change. This complex and dynamic relationship between climate change, agriculture and food security is also influenced by wider factors. Agricultural and food systems are heavily influenced by socioeconomic conditions, which are affected by multiple processes, such as macro-level economic policies, political conflict, the spread of infectious disease, etc. A recent report by the World Economic Forum warns that "food security will become an increasingly complex political and economic problem over the next few years" (WEF, 2008).

Concerted action is urgently needed to address this complex challenge. A new research initiative is needed to inform this action – one that integrates and applies the best and most promising approaches, tools and technologies emerging from numerous disciplines. The involvement of farmers, policy-makers, researchers, donors and other stakeholder groups in the research process is key. Successful mitigation and adaptation will entail not only individual behavioural changes, but also changes in technology, institutions, agricultural systems and socio-economic systems. These changes cannot be achieved without improving interactions between scientists and decision-makers at all levels of society.

The Climate Change, Agriculture and Food Security Challenge Program (CCAFS) proposes a new strategic collaboration between the Alliance of the Consultative Group on International Agricultural Research (CGIAR) Centers and the Earth System Science Partnership (ESSP – see Box 1). This alliance, with their respective partners, brings together the world's best researchers in agricultural science, climate science and Earth system science to identify and address the most important interactions, synergies and trade-offs between climate change, agriculture and food security. CCAFS will thus define and implement a uniquely innovative and transformative research programme that addresses food security in the context of climate variability, climate change and uncertainty about future climate conditions.

Although climate change is a long-term phenomenon, the actions taken over the next 10 years will be critical. The foundations must be built for responsive, adaptive agricultural technologies and policies that help people reduce their vulnerability to climate variability, while at the same time paving the way for the successful management of long-term changes.

Box 1. Organisations leading the Challenge Program

Alliance of the Consultative Group on International Agricultural Research (CGIAR) Centers
The Consultative Group on International Agricultural Research (CGIAR), established in 1971, is a strategic partnership, whose 64 Members support 15 international Centers, working in collaboration with many hundreds of government and civil society organisations as well as private businesses around the world. Today, more than 8,000 CGIAR scientists and staff are active in over 100 countries throughout the world.

The Alliance is a Center-driven coalition created by the 15 International Research Centers in 2006 to enhance collective action among the Centers and between the Centers and their partners. By joining forces to enhance impact and deliver better, more rapid results, it enables the Centers and their partners to make the most of available resources and increase their impact for the benefit of the poor in developing countries.

Earth System Science Partnership (ESSP)
The ESSP was established in 2001 to promote cooperation for the integrated study of the Earth system, the changes that are occurring to the system and the implications of these changes for global sustainability. The ESSP comprises four international global environmental change research programmes: DIVERSITAS, specialising in biodiversity and agro-biodiversity; the International Human Dimensions Programme on Global Environmental Change (IHDP), specialising in institutional, socioeconomic and human security issues related to global environmental change and the policies to address it; the International Geosphere–Biosphere Programme (IGBP), specialising in the physical, chemical and biological processes that define Earth system dynamics; and the World Climate Research Programme (WCRP), specialising in climate science.

1.2. Climate change and Earth system science

The Fourth Assessment (AR4) of the Intergovernmental Panel on Climate Change (IPCC) provides an overview of recent scientific understanding on climate change (IPCC,

2007). It brings together observations and modelling studies that confirm that human-induced temperature increases are taking place, with measurable and increasing effects on snow cover and ice caps, sea levels, precipitation patterns and tropical storm activity. It provides evidence of the impacts of these changes on a range of systems around the world, including on marine and freshwater systems, on agriculture and on forest management. Finally, it presents projections for climate change and its impacts under different scenarios over the coming decades.

There is a wealth of scenarios predicting how the global climate might change in the coming decades and over the next century. Although there are many uncertainties associated with these scenarios, it is becoming increasingly evident that regardless of mitigation efforts (undertaken today and in the future), temperatures will continue to increase over the next decades because of earlier emissions of GHGs into the atmosphere. The magnitude and frequency of extreme events are also set to increase over this period in many regions. Adaptation is therefore a necessary response to climate change. At the same time, mitigation of even further climate change is urgent if future changes are to be limited to levels that do not create irreversible environmental changes and devastate the lives and livelihoods of the most vulnerable.

Climate, however, is only one factor within the dynamic Earth system. Changes in the physical and biogeochemical environment, either caused naturally or influenced by human activities such as deforestation, fossil fuel consumption, urbanisation, land reclamation, agricultural intensification, freshwater extraction, fisheries over-exploitation and waste production, contribute to global environmental change (GEC). Earth system science takes a more holistic approach to understanding the processes and outcomes of GEC. It does this by including the interactions between land, atmosphere, water, ice, biosphere, society, technologies and economies. This approach seeks to understand the dynamics of climate change and the interactions with other types of environmental change, which together will have a great influence on food systems and food security (Box 2).

1.3. The challenge for agriculture and food security

Agricultural and food systems are complex and dynamic. Some systems are less vulnerable to short-term climate effects (for example, where they are linked to irrigated farming systems fed by reservoirs of large storage capacity). Others, for example those relying on rain-fed agriculture, have always been exposed to uncertain and extreme climate, but may now face variability beyond the current 'coping range'. In vulnerable systems, climate change threatens food security, livelihoods and economic prosperity (UNDP, 2007).

Box 2. Definitions: food systems and food security

Food systems encompass (i) activities related to the production, processing, distribution, preparation and consumption of food; and (ii) the outcomes of these activities contributing to food security (food availability, with elements related to production, distribution and exchange; food access, with elements related to affordability, allocation and preference; and food use, with elements related to nutritional value, social value and food safety). The outcomes also contribute to environmental and other securities (e.g. income). Interactions between and within bio-geophysical and human environments influence both the activities and the outcomes (Ericksen, 2008).

Food security is the state achieved when food systems operate such that "all people, at all times, have physical and economic access to sufficient, safe, and nutritious food to meet their dietary needs and food preferences for an active and healthy life" (FAO, 1996). Food security is underpinned by food systems and is diminished when food systems are stressed. This stress can be caused by a range of factors in addition to global environmental change (e.g. population pressure, changes in international trade agreements and policies, migration) and may be particularly severe when these factors act in combination.

The AR4 has gathered scientific evidence and expert opinion on the expected impacts of climate change on agricultural systems (IPCC, 2007). The report notes that climate change is already having an impact, for instance, through changes in patterns of variability and associated changes in rainfall distribution. It anticipates with high confidence that projected changes in the frequency and severity of extreme climate events, together with increases in risks of fire and pests and pathogen outbreaks, will have significant consequences for food and forestry production, and food security. The impacts of projected changes in mean climate conditions are also expected to be negative. It identifies smallholder and subsistence farmers, pastoralists and fishers as likely to be most vulnerable to the impacts of climate change.

The AR4 finds that Africa is highly vulnerable to climate change, because of multiple stresses and low adaptive capacity. Projections indicate an increase of arid and semi-arid lands, and, in some countries, yield reductions in rain-fed agriculture of up to 50% by 2020; but some parts will also get wetter. In Asia, potential changes in the monsoon, and in glacier and snow melt are perhaps the greatest threats. Sea level rise is also of great concern as coastal and deltaic areas are often heavily populated and intensively cultivated. The natural and managed habitats of fish will be greatly influenced, with declining productivity in fisheries very likely. The report recognises that, despite a decade of research on climate change adaptation, considerable knowledge gaps remain, particularly concerning the adaptive capacity of food, fibre, forestry and fisheries systems.

Climate variability and risk has always been a part of agriculture, and farmers have developed many ways of managing that risk. Enhancing adaptation strategies is an important part of the work of the CGIAR Centers. Developing drought-resistant and other abiotic stress-tolerant crop varieties, and soil and water management practices for marginal areas, for example, have long been core activities of the CGIAR Centers. Climate change introduces a new dimension to the problem. The unprecedented rate and magnitude of climate change presents great challenges to farmers, researchers and policymakers alike. The CGIAR Centers have already begun to address the climate change challenge. All have incorporated activities on climate change impact analysis, mitigation options or adaptation strategies into their research priorities and programmes, and several Centers have recently established dedicated programmes on climate change. (Some of this work was highlighted in a recent article on SciDevNet (2007), which describes how researchers are working to 'climate-proof' crops, and the key role of biodiversity in this effort; and a Special Issue of *Agriculture, Ecosystems and Environment* (Verchot and Cooper, 2008), highlights various aspects of CGIAR climate change-related science.) However, this research has not been carried out or brought together in an integrated way that highlights the interactions, synergies and trade-offs between different actions and responses to climate change.

Current efforts to increase adaptation options provide a sound basis for the next phase of research on climate change, agriculture and food security. However, this phase must go far beyond what is currently being done. New responses are needed, as well as new ways of working (Box 3). These must be instilled with a degree of urgency, reflected in the research agenda, its implementation, and in the delivery of outputs.

Box 3. Building on current investments

1. Innovations such as plant breeding for drought tolerance and heat stress, pasture and livestock management, soil and water management, and fisheries and forest management are necessary, but they will not be sufficient on their own.
2. Integrated options, based on the use of appropriate combinations of different crops, (agro)biodiversity to provide associated ecosystem services, and management practices approached at a range of spatial levels are needed, but these must be accompanied by necessary policy and institutional support. Maintaining or enhancing diversity is necessary to promote flexibility in adaptation, not only in technology and crops, but also in modes and scales of production.
3. Methods are needed to help policymakers and resource managers evaluate the trade-offs between local benefits and global goods when addressing food, energy and water scarcity (among others), and planning land use options for resilience. The goals and interests of stakeholders cannot be ignored, and reconciling these with global goods is essential.
4. Greater adaptive capacity has to be fostered, allowing communities to draw upon a range of options to support their livelihoods. This, in turn, implies a greater adaptive capacity on the part of policymakers, decision makers and scientists. An enabling institutional and policy environment is needed, and improved links among research, the policy environment and stakeholders in developing countries are required.

2. The Challenge Program

This Challenge Program provides a framework to facilitate new research on the interactions between climate change, agriculture and food security. It introduces a new partnership between the international agricultural research and Earth systems science communities which will create unique possibilities in the search for solutions to the climate change/food security problem. Research will build on the ongoing activities of both communities, but will go beyond core centre research or what is feasible under a system-wide programme within the CGIAR, by opening new avenues of interaction and synergy that will prove to be essential in tackling this most complex and urgent of global challenges. CCAFS will therefore focus on:

- Emerging avenues for adapting to a changing climate that are currently constrained by major knowledge gaps and that, because of their newness, have not yet been fully explored or mainstreamed within the CGIAR.
- Adaptation and mitigation interventions that require upstream research capacity (particularly climate, Earth systems and global change science) beyond the CGIAR's core expertise to achieve their full potential.
- Opportunities for adaptation and mitigation that require the involvement of downstream institutions (e.g. global and regional climate centres, national meteorological services, food crisis early warning and response systems) beyond the CGIAR's traditional partners.
- Robust analytical approaches and tools that will enable the CGIAR to better target technology and policy for the range of possible future climate realisations, and assess potential impacts *ex-ante*.
- Integrated approaches to adapting agriculture and food systems to a changing climate that depend on the coordination, integration and economy of scale that a Challenge Program can provide.

By producing international public goods that will help protect and enhance progress towards achieving sustainable food security and reducing poverty in developing countries, in the face of new and intensified challenges imposed by a changing climate, CCAFS contributes directly to the CGIAR's mission.

Several innovative approaches distinguish CCAFS from other ongoing work.

First, it will work at multiple spatial scales to address the often cross-scale interactions between climate and food and agricultural systems. The CCAFS targets scale up to sub-continental because (i) significant climate perturbations, and appropriate adaptation responses, may be experienced at this scale; (ii) environmental issues, and their solutions, often cross national boundaries; (iii) food system interventions related to intra-regional trade and distribution, and agricultural labour movements, are realised at this scale; (iv) existing sub-regional organisations (i.e. CORAF/WECARD, ASARECA and the RWC) provide a mechanism for coordinating national research at the regional level and scaling-up implementation; and (v) donors often plan at the regional scale and are usually keen to support regional structures.

Second, it will work across time scales, seeking to identify and develop the knowledge base and capacity for immediate actions that allow current development to sustain and prosper in the face of a changing climate. Research on adapting to climate includes management of current climate risk and adaptation to the progressive climate change anticipated over the coming decades. Similarly, work on mitigation addresses emerging mechanisms that provide immediate livelihood benefits, while reducing the GHG burden and protecting and enhancing environmental services for the future.

Third, it will emphasise the characterisation and management of uncertainty. Uncertainty is a fundamental challenge when dealing with climate at all time scales. The CCAFS will go beyond simple multi-model climate change scenarios to better characterise climatic uncertainty, and provide a rigorous framework and analytical infrastructure for developing adaptation responses that are robust in the face of uncertainty at all relevant time scales.

Fourth, it will focus on several emerging and innovative adaptation opportunities that have not yet been fully exploited, and whose potential is only partially understood. Examples include new ways to use new climate information products and services, index-based financial risk transfer products, opportunities from climate policy and carbon certification, climate-informed management of food trade and delivery systems, and management of climate-driven spatial shifts of agro-ecosystems.

Finally, it is integrative. Building on the substantial work on 'component' adaptation technologies developed by the CGIAR, its partners and its stakeholder participants, CCAFS will design and assess integrated portfolios of adaptation and mitigation interventions, with a focus on livelihoods and food security at household and higher levels. In between the paradigms of 'planned' adaptation to a known change and the 'risk reduction by diversity' approach to increased uncertainty, it will explore 'planned diversity' and 'diversity of plans', as elements of a higher order risk management strategy.

2.1. Goal

- To overcome the additional threats posed by a changing climate to achieving food security, enhancing livelihoods and improving environmental management.

CCAFS will address this goal by generating the knowledge base and toolsets to empower and assist farmers, policymakers, researchers and donors to successfully manage agricultural and food systems so as strengthen food security, enhance rural livelihoods and improve environmental sustainability in the context of the challenges arising from current climate variability and progressive climate change.

2.2. Objectives

1. Close critical gaps in the knowledge of how to enhance – and manage the trade-offs between – food security, livelihood and environmental goals in the face of a changing climate.
2. Develop and evaluate options for adapting to a changing climate to inform agricultural development, food security policy and donor investment strategies.
3. Enable and assist farmers, policymakers, researchers and donors to continually monitor, assess and adjust their actions in response to observed and anticipated changes in climate.

Objective 1 is geared towards outputs; Objective 2 is geared towards outcomes; Objective 3 is geared towards impacts.

2.3. Research themes

CCAFS has six main research themes, grouped into two sets.

Set 1: Diagnosis and developing the knowledge base - setting the research context and analysis of trade-offs between improving livelihoods, food security and environmental benefits

- Theme 1: Diagnosing vulnerability and analysing opportunities
- Theme 2: Unlocking the potential of macro-level policies
- Theme 3: Enhancing engagement and communication for decision-making

The first three themes provide an essential foundation in the form of a strong analytical and diagnostic framework, grounded in the global change policy environment, and know-how to effectively engage rural communities and institutional and policy stakeholders. Targeting food security, poverty reduction and sustainable natural resource management interventions that are robust in the face of a changing and uncertain climate requires a strong *ex-ante* analytical capacity to diagnose points of vulnerability, and assess the impacts and trade-offs between socioeconomic and environmental goals associated with alternative strategies. The global policy environment increasingly influences the opportunities and constraints to local- and national-scale actions that can be taken in response to a changing climate, and in some cases may be responsive to evidence obtained from the type of research that CCAFS will undertake. Understanding vulnerability, identifying appropriate interventions, assessing their effectiveness, and leaving a sustained legacy of improved decision making all depend critically on effective modes of engagement with a range of stakeholders.

Set 2: Developing adaptation pathways and identifying mitigation options for agricultural and food systems in the face of climate change

- Theme 4: Adaptation pathways based on managing current climate risk
- Theme 5: Adaptation pathways under progressive climate change
- Theme 6: Poverty alleviation through climate change mitigation

This 'Adaptation' set of Themes will identify and develop instruments, technologies, practices and partnerships needed to decrease the vulnerability of rural communities to a variable and changing climate. The three Themes involve different interventions that build on distinct bodies of knowledge and likely require the involvement of different institutions. These Themes have been designed to develop outcomes achievable from the added-value of a CGIAR–ESSP collaboration. Research in these three Themes will build on the ongoing core work of the CGIAR Centers; on advances in knowledge of the global climate system, of management of climate risk and adaptation to climate change; and on the knowledge and methodology developed in the first set of Themes. Collectively, these three Themes will demonstrate and assess the feasibility, effectiveness and acceptability of integrated strategies for advancing food security, livelihood and environmental goals in the face of a changing climate; and will identify and prioritise institutional and policy options for overcoming obstacles to implementing these strategies at the scale of the development challenge. The process of addressing these questions in the research regions will enhance capacity (in the form of analytical tools and infrastructure) to better target and evaluate a range of adaptation options.

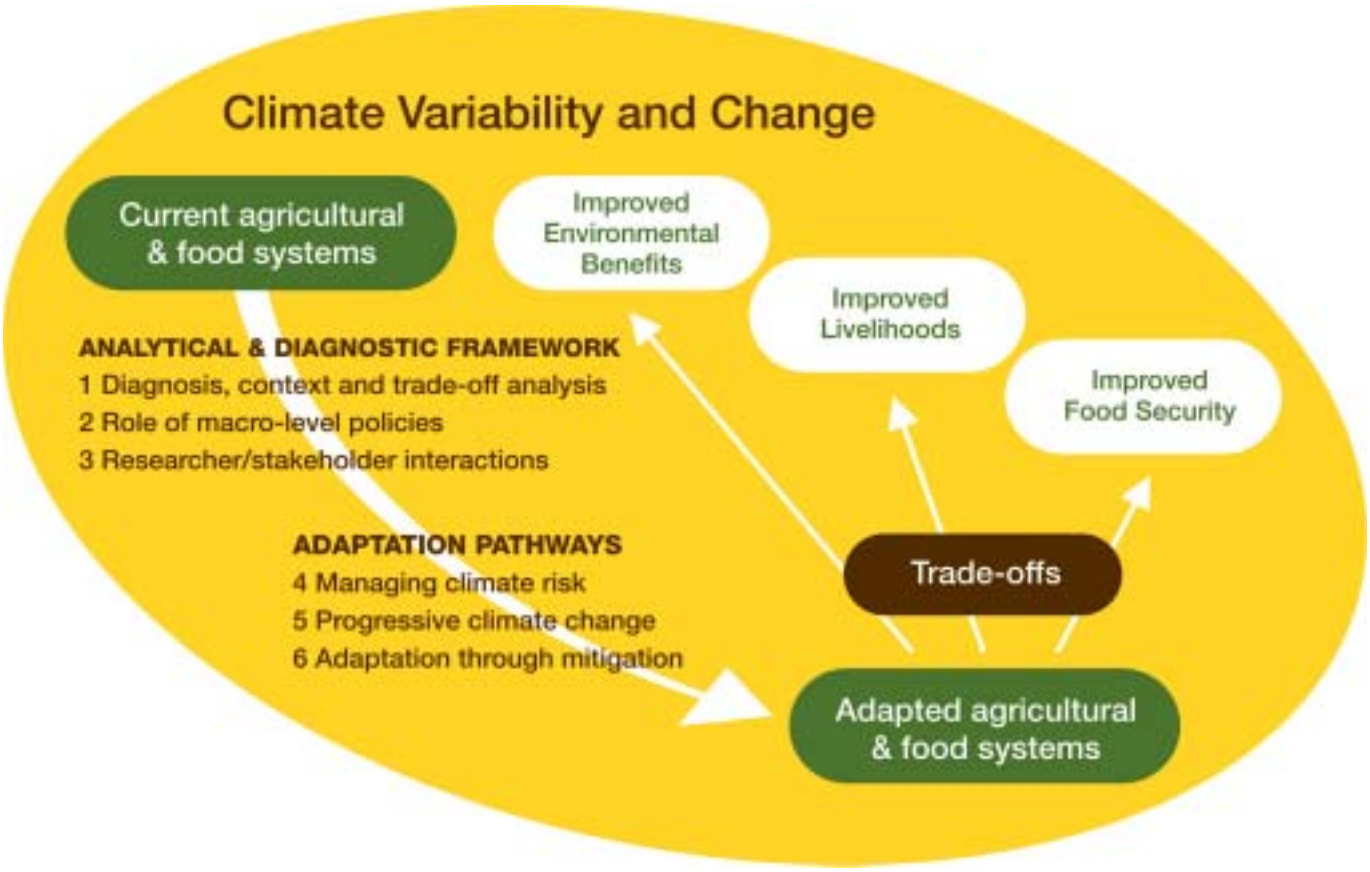

Figure 1. Schematic presentation of the CCAFS research framework and the Science Themes.

2.4. Research outputs and international public goods

Building on the outputs of the research themes, CCAFS will produce a set of international public goods (IPG) that include:

- An enhanced analytical framework, suite of tools and infrastructure to enable stakeholders to diagnose vulnerability; and to better target and assess the likely impacts of adaptation, mitigation and policy interventions.
- A repository of information on vulnerable populations and probabilistic projections of climate impacts under a set of development scenarios.
- Knowledge on how to best enable stakeholders to access and use relevant climate information products and knowledge to improve food security, livelihoods and management of the natural resource base in the face of a variable and changing climate.
- Evidence of feasibility, acceptability and impacts (food security, livelihood, environmental) of comprehensive climate change adaptation strategies and mitigation opportunities, evaluated across multiple contexts.
- Synthesised knowledge of how best to target and implement innovative climate change adaptation and mitigation strategies and policy.
- Innovative approaches for integrated technical and policy adaptation and mitigation based on new understanding of interactions across spatial and temporal levels and embedded in institutional structures.
- Determinants of the uptake of adaptation strategies, and institutional and policy options for overcoming obstacles identified and prioritised.
- A network of trained research leaders, and a Young Scholars Certification Program.

2.5. Outcomes and impact pathways

CCAFS seeks to protect and enhance progress toward the broad food security, livelihoods and environmental management goals of the CGIAR, in the face of new and intensified challenges imposed by a changing climate. It will contribute both to ancillary impacts with stakeholders at project locations and in focus regions, and to primary impacts that are longer-term, global and based on IPG. Impacts may include changes in agricultural production, via the scaling up of appropriate adaptation options from the study regions; impacts on environmental conditions, via adaptations that reduce emissions, conserve biodiversity and enhance the efficiency of natural resource use; positive changes in economic conditions, via changes in producers' and consumers' economic well-being; changes in market

conditions (prices and efficiency), via changes in production, reduction of risk, and market information flows; and changes in social conditions, via improvements in food security, increased empowerment and reduced vulnerability.

CCAFS activities are orientated towards three high-level outcomes to achieve impact:

1. Climate variability and climate change issues mainstreamed into national, regional and international agricultural development strategies and institutional agendas.

   Changes in development strategies and institutional agendas will affect target populations through several pathways. For example, policies that provide incentives and an enabling environment for pro-poor rural financial risk transfer services can reduce the need to sell off productive assets in the event of a climate shock and overcome the reluctance of lenders to extend credit to farmers to purchase inputs. Reorienting the mandate and data policy of national meteorological services toward delivering climate information products and services through extension services can contribute toward greater climate awareness and proactive decision–making for a wide range of stakeholders.

2. Innovative information products and communication processes developed and maintained at local, national and regional levels.

   Uncertainty is central to the climate challenge, so effective communication of relevant information and the capacity to assess and adjust decisions in response is necessary for empowering all stakeholders to be agents of change. There will be different impact pathways for different stakeholders, ranging from information products and training delivered to intermediaries and rural communities, to implementing new approaches for enhancing science–policy dialogues for decision-making.

3. Effective, climate-informed decisions made relating to:

- Setting priorities to identify and fund research and development agendas and adaptation policies and investments at international and regional levels
- Promoting and implementing adaptation options that render rural communities better able to monitor and adapt to climate variability and change, with full knowledge of the tradeoffs that arise between the multiple objectives of increasing food security and sustaining livelihoods and the environment
- Establishing and maintaining a supporting institutional, policy and infrastructural environment so that adaptation options are effective.

Forward-looking analytical tools that integrate key drivers with local-level characterisations will provide an essential capacity to target adaptation policy, investment and intervention where they will have greatest positive impact in location-specific contexts.

CCAFS will work towards outcomes across scales and levels (Cash et al., 2006), which constitutes a fundamental integration challenge. This will be addressed through the development and use of an integrated framework to place the case-study work in a broader, macro-level context.

The global perspective complements and enriches local, national and regional scales of inquiry in various ways. First, targeting the most promising adaptation opportunities for local implementation and testing with local and regional development partners depends on evaluation that considers the broader systems' dynamics and interactions, such as market effects and environmental externalities, to ensure that the poor truly benefit. Climate change and other drivers of change that have significant impact on the welfare of the poor can only be understood in the context of global socioeconomic and cultural trends. Second, ensuring that poor and vulnerable people benefit from the adoption of specific adaptation options requires understanding of the likely distributional impacts, which is best assessed at a broad, strategic scale. Third, many pro-poor agricultural development stakeholders operating within an international or regional context will increasingly depend on evidence-based investment decisions to help them make difficult choices about targeting their own efforts.

CCAFS will contribute to a global overview of the successes and failures of adaptation options to climate change, which can help these development stakeholders avoid repeating failures and accelerate the transfer of successes across regions. Finally, a more comprehensive set of evaluation tools and databases for building future scenarios of change will provide more useful knowledge and decision-support capabilities that can inform targeting of technology and policy, and will be of direct utility to researchers globally.

The strategy for converting the outputs of CCAFS into outcomes and impact will be oriented towards the various types of output that will be delivered by the Themes. All outputs will be delivered by working through partnerships. Methodology outputs (such as databases, diagnostic toolkits and evaluation frameworks) will be delivered through multi-level research partnerships that range from the international science community to national agricultural research systems (NARS) and public-sector service delivery organisations. Developmental outputs such as adaptation options will need different types of partnership, and these may include researchers, government development agencies, NGOs and producer associations, private-sector investors and service providers, and other organisations involved in implementing activities on the ground. Policy outputs may be delivered through coalitions of policy partners and decision-makers, researchers, regional information networks, pro-poor civil society organisations, and development donors. All these outputs have implications for capacity building among development partners.

Attributing impacts to particular Program outcomes, and outcomes to particular research outputs is a challenge, but best practice guidelines will be used to evaluate the impacts of CCAFS (Walker et al., 2007). A set of appropriate baseline indicators, on agricultural productivity, rural livelihoods, and bio-geophysical attributes, will be collected in the study regions at the start, so that ex-post impact assessment can be carried out.

3. Research agenda

3.1. Theme 1: Diagnosing vulnerability and analysing opportunities

This Theme will design and implement an analytical framework for diagnosing the vulnerability of agriculture, food security to climate variability and climate change; and for analysing the opportunities for adaptation and mitigation together with their tradeoffs on poverty, food security and the environment.

There is a considerable body of work on the likely impacts of increasing CO_2 levels, increasing temperatures, and shifting rainfall amounts and patterns on crops, pests, ecosystems and natural resources (MA, 2005; UNEP, 2007; Molden, 2007; IPCC, 2007). While some work has also been done on likely impacts on the agricultural, water and forestry sectors explicitly (e.g. Bruinsma, 2003; IAASTD, 2007), the level of aggregation in such studies is high and the level of detail low. The IPCC AR4, for example, presents the most authoritative voice on climate change, but it remains a review of available published research rather than a dedicated and commissioned effort to unravel specific sector impacts, such as those on agriculture. Given the heterogeneity of climate change impacts at different spatial levels, a serious knowledge gap exists. In addition, relatively little is known about the interactions of climate and increasing climate variability with other drivers of change in agricultural systems and on broader development trends. Perhaps most importantly, we do not currently possess a framework to analyse the implications (both positive and negative) of human responses to the climate challenge in terms of regional food security and the preservation of important ecosystem services, upon which the long-term sustainability of global agriculture must be based. Such interactions may themselves be strong determinants of vulnerability to climate change. While the broad trends may be discernible, much more detail is required concerning localised impacts of climate change, effects on livelihood systems, and options that can increase the well-being of people dependent on natural resources for their living.

There is, thus, a need for methods, analytical frameworks, models, databases, and system metrics to enable us to assess the likely impacts of climate change and climate variability on agricultural and food systems, particularly in the context of other social and economic changes. These same tools can be used to help guide decisions in this CP – and outside it – concerning the allocation of research resources, the specific research topics, and where to execute these in order to optimise the efficacy of CCAFS activities. We also need methods and tools to assess the likely impacts of different interventions – adaptation and mitigation options – in terms of their effects on poverty alleviation, food security and the environment. What the likely impacts of different interventions will be is a critical input into identifying the tradeoffs and, thus, the best-bet options for specific climate challenges.

The tools needed for both these tasks (assessing the impacts of climate change on systems, and assessing the impacts of interventions on the same systems) are essentially the same: a comprehensive and quantitative framework that both interrogates and pulls together what is known about the climate system, the ways it may change in the future, the associated impacts on agro-ecosystems, the livelihoods of those who depend on them, food security and feedbacks to the Earth system. While much is known about many components, no integrated framework yet exists. There are key gaps and uncertainties in knowledge concerning some processes, in model capacity, and in high-resolution databases. The work proposed under this Theme is designed to address these gaps, many of which the CGIAR and the ESSP are uniquely placed to fill. We also propose to use the integrated framework that is developed here to help set in place systems for monitoring and evaluating CCAFS research activities. Towards the end of CCAFS, the framework will also be used for *ex-post* assessment of the research work, its outputs and its outcomes, in relation to a 'baseline' set of key indicators that will be measured at the start in the regional case study sites.

Drawing from the wide range of candidate models (climate, biophysical, integrated), analytical methods, and databases to be used in CCAFS, critical gaps need to be assessed and acted upon. Procedures to fill these gaps need to be implemented for evaluation in the study regions, with both researchers and different stakeholders working in tandem.

3.1.1. Research questions

1. What changes in climate and climate variability are anticipated in the selected study regions and in other candidate study regions in the coming decades that will have a direct bearing on food production systems, natural resources and rural livelihoods? *(i.e., what is going on with the climate system, and how certain are we of these changes?).*
2. What are the specific impacts of climate variability and climate change on agricultural and food systems and the people who depend on them directly for their livelihoods, both now and into the future? *(i.e., how is the system vulnerable?)*

3. Where are the impacts of climate variability already large? Where are climate change impacts in the future likely to remain large or emerge as important challenges? And where are adaptation and mitigation options likely to have large effects on poverty alleviation, food security and environmental sustainability? *(i.e., where and how can we intervene appropriately now?)*
4. How will agriculturally-based livelihood systems evolve in the coming decades, specifically in light of climate change, but also in light of population growth, globalisation of markets, and development investment policy? What will be the resultant vulnerabilities and opportunities, and how may response strategies play into this changing set of biophysical challenges? *(i.e., how will things change in the future, and how can we prepare?)*
5. How will climate change affect biogeochemical cycling in the selected study regions, in systems that are nitrogen (highland) or phosphorus (lowland) limited?

3.1.2. Activities

- Identify baseline indicators for the case-study sites with regional and national partners, relating to agricultural systems and production, natural resources, poverty, climate, soils, economics, policy and institutional environment and human capacity. These will be defined for the purposes of CCAFS and measured directly (or suitable proxies used) in the case-study regions (with Themes 4–6).
- Characterise recent trends and variability in climate for the study regions and the ability of climate models to simulate these features. Characterise of other key trends, such as changes in agricultural production, food security, land-use change, poverty levels, and soil, water and other supporting ecosystem services, that provide a broad context for CCAFS activities with stakeholders in the study regions (with Themes 4 and 5).
- Assess and adopt methods for downscaling climate change information specifically for agriculture and natural resources management, including a range of timescales varying from the diurnal to multi-decadal; quantify the skilful spatial and temporal limits to prediction; and quantify the uncertainties associated with these methods, reflecting the information needs of different stakeholders (with Theme 5).
- Develop and apply a conceptual framework, based as far as possible on existing work to guide the development of an integrated suite of appropriate models, methods and databases, that will be used to assess the impacts of climate change and specific interventions on agriculture and food systems; evaluate the trade-offs between impacts on livelihoods, food security and the environment; and carry out specific *ex-ante* impact assessment studies and priority-setting activities as required by the other Themes. A wide range of stakeholders will be involved in the design and implementation of the framework, to ensure that it meets the varied needs of CCAFS (across Themes).

3.1.3. Methods

CCAFS will integrate the increasing body of literature exploring the explicit links between climate change, agriculture, food security and natural resources (e.g. Bruinsma, 2003; Ericksen, 2008; Gregory and Ingram, 2008; Ingram et al., 2008) within a framework based on the archetype approach (Lüdeke et al., 2004; Eisenack et al., 2007) to better investigate the links between climate change, food security and the resulting societal consequences. This will bring together the latest conceptual advances with empirical knowledge from the field to identify a small number of key cause–effect relationships. These would then be modelled using innovative techniques that are able to integrate knowledge from different sources and of different types. The resultant model will be used to diagnose different situations where specific hazardous developments are being manifested, and to assess the possible impacts of specific interventions and management options. A wide variety of information sources will be used to implement the approach, including point and spatial data, existing case-study syntheses and expert assessment.

An indicative data integration and modelling framework is shown in Figure 2 that draws these various elements together, to provide an integrated package of approaches that will be used to assess a wide variety of adaptation and mitigation options and policy instruments under a range of climatic and socioeconomic futures. Detailed databases coupled with a querying system (GEDIT, see below) will be linked to suites of models that describe the economic and biophysical dynamics of agricultural production in relation to the climate system and that are able to incorporate Earth system dynamics to assess the feedbacks of specific economic and biophysical strategies on major system variables, such as land use, soil carbon and fertility, water supply and pollution, trace gas emission and biodiversity.

A variety of methods and tools will be used in pursuit of Theme outputs. The following elements will be addressed:

Analysis of Global and Regional Climate: climate models are the only practicable means to predict global future climate. Models used in IPCC AR4 exhibit strikingly differing levels of skill in simulating the current climate and in consistency concerning projected future climate, particularly rainfall amount, the large-scale patterns of climate that cause variability and the more detailed simulation of variables, such as cloud and diurnal temperature to which crop yield is highly sensitive. The fidelity of climate models on these counts is highly region-specific. Only limited work has been done to date on assessing the ability of different climate models and downscaling methods (both numerical and empirical), within the context of agriculture, to reproduce observed present-day climate patterns in response to historical forcing experiments in the study regions. What studies have been done point to inadequacy for an assessment of future agricultural vulnerability. This needs to be addressed. In addition, work is being done on coupling weighted

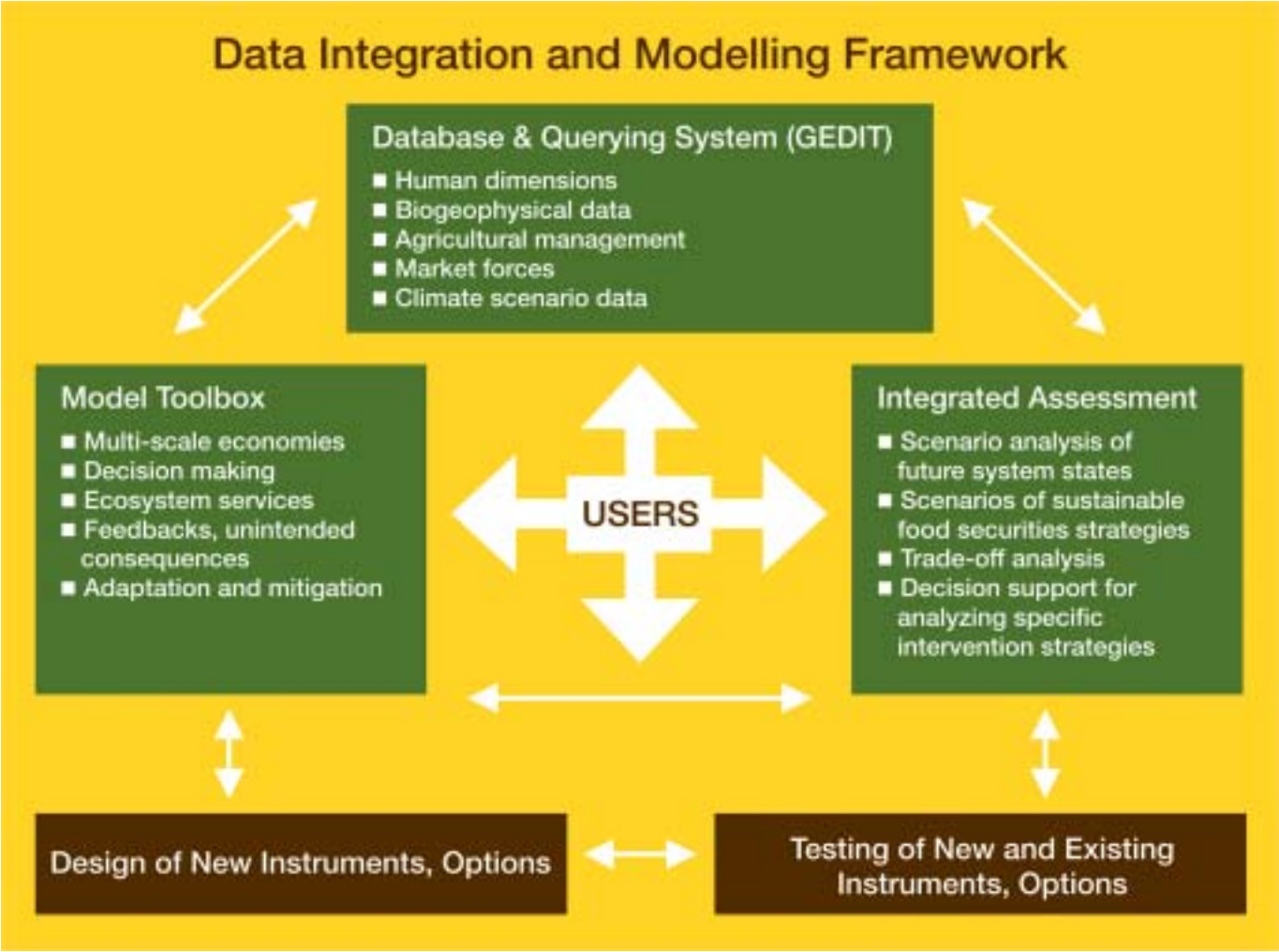

Figure 2. Data and integration modelling framework for CCAFS.

ensembles of regional climate simulations to crop models in an effort to estimate potential impact on future yields of important crops (e.g., Lobell and Field, 2007). Extending these methods while tailoring a regional focus and methodology to the needs of CCAFS should prove a fruitful pathway for developing information suitable for agricultural application.

A particular problem and crucial information gap lies between seasonal prediction (< 12 months) and forthcoming decades when the GHG forcing is sufficiently strong to exceed internal variability (2020s and beyond). This gap corresponds with time periods for which there is great user demand for information. Novel methods need to be developed to deal with this hiatus. For example, information regarding regional natural variability as it has existed in the past is being developed, and can be used to characterise uncertainty ranges in climate projections going forward. This is one way in which decision-makers may be able to take account of this component of climate variability.

Development and application of GEDIT (the Geospatial Diagnostic Toolkit): Diagnosis of the vulnerability of agricultural and food systems in response to climate variability and change needs to be based on robust, quantifiable metrics that can be tracked. A Geospatial Diagnostic Toolkit (GEDIT) will be established for each study region to identify hot-spots of change, monitor CCAFS progress through time, assess the efficacy of policy and technology interventions and allow multi-site comparisons and extrapolation. In addition to yielding important insights into the capacity of food production systems to assure food security in the light of ongoing climate and other changes, GEDIT will also permit broad access to decision-making tools of value to local stakeholders as well as to macro-scale policymakers. Arming the next generation of agricultural researchers and the public with state-of-the-art agronomic and environmental system information sets will result in important spin-off benefits in areas of the world where these may be the only practicable sources of quantitative information upon which to design interventions.

GEDIT will involve the development of spatially refined indicators of food production systems that can be mapped and their potential sensitivities to climate variables. Its design will take advantage of new open-source GIS protocols and web-based data distribution capabilities. It will encompass a broad suite of spatial and statistical data encompassing point-scale and gridded socioeconomic and

bio-geophysical datasets that users will be able to explore and manipulate in various ways. Example data themes to be included are crop and livestock distributions, human population, poverty rates, land use and land cover, infrastructure, climate, and ecosystem services inventory. These datasets, which will need to be constantly replenished and updated, will be organised according to food security themes and presented in the spatial context of a variety of organisational frames. This flexibility will accommodate contrasting elements, such as administrative unit, agro-ecological zone and river basin, and reflect different management units, for example the provincial government, river basin, agro-ecological zone, etc. Under any unit structure, the system will be used to analyse the changing nature of food security in relation to human needs and activities over local-to-regional and case-study scales. The GEDIT approach will be built around partnerships among users and providers of these data sets (including the wider CGIAR and ESSP communities), and CCAFS will catalyse the requisite workshops and other professional interactions to take advantage of these diagnostic capabilities.

Future assessments of vulnerability and food security in evolving agricultural systems: Scenario analysis will be undertaken to assess the possible trajectories of agricultural and food systems in the case-study regions and the likely impacts of different pathways on food security, livelihoods and the supporting natural environment. Key tipping points in system productivity and vulnerability will be identified, so that opportunities for dealing with them may be defined and assessed. Links will also be made to formalise results in the context of the GEDIT system.

3.1.4. Expected outcomes

- More effective priority setting and research resource allocation in the face of climate change, arising from a more complete understanding of the impacts of climate change on agricultural and food systems.
- The formulation of a responsive and effective international research and donor agenda for the next two decades, as a result of a comprehensive assessment of the state-of-the-art concerning climate change impacts on agriculture and the food system, that identifies key knowledge and data gaps.
- Increased uptake of appropriate options in the regional sites, and their homologues elsewhere, whose trade-offs between food security, livelihoods and environmental impacts have been assessed using a coherent analytical framework to chart the efficacy of different adaptation and mitigation options.
- More informed regional, national and local decision-making and enhanced adaptive capacity as a result of stakeholder adoption of sets of tools that provide information to understand the nature and context of climate change impacts on poverty, food security and the environment.

Climate variability and global climate change impacts and

3.2. Theme 2: Unlocking the potential of macro-level policies

This Theme focuses on identifying the opportunities as well as the constraints inherent in macro-level policies. It investigates unlocking their potential for adaptation and mitigation to enhance developing-country agricultural growth, food security, poverty reduction and environmental sustainability through innovation in the design and execution of policy interventions.

options for mitigation and adaptation are deeply embedded within both a highly dynamic policy environment (Stern 2006; IPCC, 2007) and a complex Earth system (Kabat et al., 2004; Lüdeke et al., 2004). Appropriate macro-level climate change policies and institutions can stimulate pro-poor investment, increasing the profitability of environmentally sustainable practices to generate income for small producers, and create investment flows for rural communities. For example, post-Kyoto carbon regimes could help finance developing-country climate adaptation and mitigation strategies, while at the same time supporting agricultural and rural development (FAO, 2007). This will require appropriate incentive mechanisms to create a 'balanced portfolio' of development strategies that foster adaptation and take advantage of the mitigation benefits of intact ecosystems (Kindermann et al., 2006).

At the same time macro-level trade, development or other policies can alter vulnerabilities to climate stresses and influence the potential of mitigation efforts at more local levels (O'Brien and Leichenko, 2000). Critical issues under this research area include understanding the interrelationships among macro-level policies, poverty alleviation, agriculture, climate change outcomes and unintended consequences on the environment; and how these policies can be directed towards both improved coping and adaptation and mitigation strategies for the rural poor under climate change while enhancing environmental sustainability.

A broad suite of macro-policy objectives is directly linked to sustainable development and food security, including issues as far-reaching as globalisation, implementation of climate control agreements, pursuit of development imperatives, such as the Millennium Development Goals (MDGs), and adherence to the Conventions on public goods: on Desertification, Biodiversity and Wetlands. Implementation of these objectives embodies a complex range of policy instruments. For example, international agreements to control climate change are apt to include the internalisation of costs often thought of as externalities.

While this is a laudable global commons goal, the capacity of developing countries to weigh the positive and negative aspects of dealing with such internalisations as adaptation beyond 'good development' policies or alternative post-Kyoto global carbon mitigation regimes in the context of agricultural trade, subsidies, public finance and other market policies, is a clear, but unmet, need.

In these analyses, it will be crucial to understand and assess the potential tradeoffs and feedback effects. Climate-focused policy objectives, for example, may lead to unintended and potentially contrary outcomes on rural livelihoods as well as on environmental systems that could reasonably be avoided. Thus, a lending policy aimed at helping climate-proof food production systems by developing large-scale irrigation systems may have the inadvertent result of simultaneously destroying the livelihoods downstream of artisanal or commercial fisheries by the emplacement of large reservoirs that distort natural discharge and temperature regimes, as well as sediment and nutrient flows. Macro-level policies could therefore have additive and potentially synergistic effects (both positive and negative) that will affect global economic, climate and environmental security both directly and by facilitating or frustrating adaptation and mitigation pathways at the local level. The tools and knowledge base to assess these issues from the necessary integrative standpoint are currently not available and the full impacts of these macro-level strategic issues thus remain poorly understood.

3.2.1. Research questions

1. How do different climate policies affect developing-country agricultural growth, food security, poverty and environmental sustainability?
2. How could local-level technical and policy interventions for adaptation and mitigation be fine-tuned to be more effective in the context of macro-level policies?
3. How could the macro-policies that drive globalisation be adjusted to both minimise adverse environmental impacts of embodied levels of exchanged input goods (e.g. virtual water, nutrients) and services and promote rural livelihoods?

3.2.2. Activities

- Develop integrated scenarios for analysis of international and national policy shifts, institutional innovations and concrete investments that could be integrated to support mitigation and adaptation strategies that bring real benefits to the rural poor (with Theme 1, and as part of the scenario activities).
- Assess the impact of carbon taxes and alternative cap-and-trade regimes on developing-country agricultural and economic growth, food security, poverty and environmental sustainability based on scenario analysis linking general equilibrium models with detailed agricultural (crop, livestock and forestry) partial equilibrium models and integrated assessment (with Theme 6).
- Examine the implications for climate change of international and national strategic agricultural development policies and the need for adaptation policies beyond 'good development policy'.
- Quantify the capacity of the Earth system to provide the resources necessary under selected macro-economic policies, and thereby assess the long-term capacity of the environment to deliver these ecosystem services and ensure rural livelihoods on a multi-decadal basis.

3.2.3. Methods

Investigating the effects of alternative macro-economic policies and institutions on climate adaptation and mitigation strategies under a range of climate and socio-economic futures will require an integrated package of approaches (Figure 2). Three main components will be linked: (i) a detailed database of human dimensions, crop research, natural resources, climate and other Earth system science and econometric information sets; (ii) models uniting the economic and bio-geophysical dynamics of agricultural production (crop, livestock, forestry and aquatic resources), with temperature and precipitation scenarios downscaled from general circulation models (GCMs) and regional climate models (RCMs); and (iii) established integrated assessment models for climate change, but incorporating Earth system dynamics to assess the 'downstream' impacts (i.e. feedbacks) of sector-specific economics and biophysical strategies in the context of major system variables (i.e. land and soil carbon and fertility, water supply and pollution, trace gas emission and biodiversity).

Analysing how macro-policies will affect outcomes of adaptation and mitigation options on changes in regional food availability, land use, water use and agricultural growth under different scenarios. Outputs will be incorporated into a global general equilibrium model in order to link the changes in agriculture and food systems to other key sectors of the economy. Over the course of CCAFS, this research will move toward a dynamic coupling of these components to study linkages and trade-offs among agricultural markets, land use, the economy, soil and vegetation and water as they affect carbon balance and the major nutrient cycles, which in turn will define agricultural sustainability at the macro-scale. Quantitative analyses will be complemented with qualitative data and studies, including expert and focal group interviews.

Results of the modelling and data analysis will be synthesised with the current literature to assess the effects of macro-level policies on rural livelihoods and poverty alleviation as an integral component of the overall CCAFS implementation.

3.2.4. Expected outcomes

- Enhanced knowledge base on the effectiveness of macro-level climate change mitigation strategies and other economic, environmental and development intervention polices for supporting adaptation in

agriculture and natural resource management.

- Informing the ongoing negotiations of the UNFCCC and the assessment processes of the IPCC by conducting a comprehensive scenario analysis that compares macro-level mitigation and adaptation policies and investments on the basis of their overall benefits in developing country agriculture and on the livelihoods of the poor.
- Direct and tangible support to the UNFCCC Nairobi Work Programme on Impacts, Vulnerability and Adaptation to Climate Change by directly focusing on its two key objectives: "(i) to assist developing countries to improve understanding and assessment of impacts, vulnerability and adaptation and (ii) to assist all Parties to make informed decisions on practical adaptation in light of current and future climate variability and change".

3.3. Theme 3: Enhancing engagement and communication for decision-making

This Theme will develop and institutionalise processes for researcher–stakeholder interaction that address decision-making needs for responding to climate change. It will promote a more effective use of research for enhancing livelihoods and food security, while at the same time achieving environmental goals.

Responding to climate change and improving food security requires multiple stakeholders to develop their capacity to anticipate and plan for changing conditions and uncertainty. This calls for a better understanding of the gaps between stakeholders' available knowledge and their needs for information to make better adaptation decisions.

Successful mitigation and adaptation will entail not only individual behavioural changes, but also changes in technology, institutions, agricultural systems and socio-economic systems. These changes cannot be achieved without improving interactions between scientists and decision-makers at all levels of society, in order to better match supply and demand of information, to develop and share appropriate adaptation tools, and to continually assess and address the need for new resources and information (Moser and Dilling, 2007). Vogel et al. (2007) note that the attempt to produce 'useful' science often occurs separately from the study of the science–practice interface. Consequently, decision-makers and managers do not receive or use the information that is produced, and vulnerability to environmental change may remain high, despite new scientific knowledge. These authors point to the need for improved communication and engagement, noting that both the science and the practices change as the result of increased researcher–stakeholder interactions, "sometimes in unexpected or unintended ways" (Vogel et al., 2007, p. 351). The type of communication and engagement is important, and strategies may include participation, integration, social learning and negotiation. An important point emphasised by van Kerkoff and Lebel (2006, p. 445) is that "the unique contribution of research-based knowledge needs to be understood in relation to actual or potential contributions from other forms of knowledge."

Given the complex, dynamic and uncertain nature of climate change and its interactions with the other social, economic and political processes driving agricultural development and food security, innovative methods and tools need to be developed to improve communication between researchers and stakeholders. An example of such a tool is the 'learning wheel' developed as part of the Integrated Natural Resource Management (INRM) task force of the CGIAR (Campbell et al., 2006a, b). This tool is based on principles and operational guidelines that present a new way of approaching research and development.

CCAFS research will further develop and apply such approaches to account for the new challenges that climate change introduces to the management of resources. It will draw upon experiences of how farmers and communities already adapt to climate variability and extreme events, and assess the role and relevance of local knowledge and experience for adaptation to the uncertain and changing conditions of the future. It will also develop and implement new approaches to communication and exchanges between researchers and stakeholders involved in the different components of the project – approaches that take into account the diversity of cultural and cognitive frameworks for understanding climate change, including how they relate to different beliefs, values and worldviews (Orlove et al., 2004; Roncoli, 2006). A focus on communication and understanding the information needs of stakeholders is a minimum requirement for ensuring that CCAFS results are used by decision makers, as all information will only be used if stakeholders believe that it is credible, has legitimacy and is relevant to the problems facing them, as they perceive them.

Communication and engagement approaches must take into account the social, economic, institutional, political and cultural contexts in which both research decisions and stakeholder decisions are made, in relation to agriculture, food security and climate change (Vogel and O'Brien, 2006). These contexts influence the capacity of decision makers to implement change, and they define the barriers and constraints to adaptation. Simultaneously, they also influence the type of research that is undertaken, and the types of adaptations that are prioritised or promoted. CCAFS research will focus on new models of interaction that not only take into account the different values, interests and perspectives of researchers and stakeholders, but also recognise that the outcomes of adaptation will have different consequences for different stakeholders. Successful adaptations for one group of stakeholders may, for example, increase the vulnerability of other

stakeholders. Furthermore, successful adaptations must be sustainable, such that they do not increase poverty and the degradation of resources, or accelerate environmental change (Eriksen and O'Brien, 2007). Ensuring that negative feedback across levels of governance and stakeholders are minimised requires an ongoing consultative process and dialogue between researchers and decision-makers (Regan, 2007).

A flexible and adaptive management process may emerge as the most successful means for addressing the complex and dynamic interactions and uncertainties related to progressive climate change, agriculture and food security. Consequently, the development of robust processes that ensure a continuing dialogue between researchers and stakeholders will be an underlying element of CCAFS. It will represent a collaborative learning process, involving not only CGIAR and ESSP researchers, but also experts with skills in facilitation and human development, knowledge brokers and development practitioners who can help to integrate across disciplines and perspectives. These processes will ensure that CCAFS results are used effectively in national- and local-level policy and decision-making processes on adaptation.

3.3.1. Research questions

1. What are the gaps between stakeholders' available knowledge and their needs for information to make better adaptation decisions?
2. How do different models of researcher-stakeholder interactions (e.g. participatory, boundary organisations, integral, or learning) facilitate the development and implementation of different adaptation and mitigation strategies?
3. What mechanisms best strengthen the science-policy interface and promote a more effective use of research for enhancing livelihoods and food security, while at the same time achieving environmental goals?
4. How can the successful models be institutionalised in diverse local contexts and in the face of both uncertainty and ongoing change?
5. How can communication and translation of climate and other types of information (e.g., market information) best help different groups of stakeholders identify adaptation pathways, given that exchange of information between scientists and information users is often problematic and contested?
6. What are the trade-offs between research messages that translate into clear action versus more complex messages that raise a range of solutions?

3.3.2. Activities

- Map out the institutions relevant to agriculture, food security and adaptation to climate change in specific contexts and identify how they relate to one another, as well as the factors that constrain institutional actions (with Themes 4–6).
- Investigate the decision-making (or policy) context for key issues, particularly the use of information and the role of research in supporting or contributing to these decisions. Use historical case studies that look at instances of very risky decisions and the role of research in these decisions. Document lessons learned about institutions and decision making (with Themes 2, 4–6).
- Investigate how institutional actions interact with local knowledge, values, beliefs and cultural factors to facilitate or constrain responses to climate change (with Theme 4).
- Carry out comparative case studies based on different models (e.g. participatory, boundary organisations, integral, or learning) of researcher–stakeholder interaction, followed by a longitudinal analysis of adaptation practices and their social and environmental consequences.
- Establish iterative learning processes and dialogues with stakeholders, where approaches and outputs as well as research questions are continually refined to be more appropriate and useful over time (with Theme 2).
- Convene workshops to evaluate and assess the state-of-knowledge on researcher–stakeholder interactions.
- Develop, test and evaluate a new model of researcher–stakeholder interaction that specifically addresses decision-making and responses to climate change.

3.3.3. Methods

Institutional analysis: This will be carried out across regions and scales, using frameworks and methods described by Bandaragoda (2000), Matsaert (2002) and Messer and Townsley (2003). Different forms and models of interaction will be assessed and evaluated in relation to the particular challenges of climate change, and hybrid models will be developed. For example, research may focus on the effectiveness of participatory approaches to climate change adaptation (Roncoli, 2006); on the role of boundary organisations as an interface between researchers and stakeholders (Vogel et al., 2007); on participatory, integrated assessment and social deliberation (Kemp and Martens, 2007); and on the use of integral frameworks for transmitting and translating information between researcher communities and decision-makers (Hochachka, 2004).

Case studies: The guidelines and principles developed by Campbell et al. (2006a,b) will serve as a point of departure for developing case studies of researcher–stakeholder interactions. These case studies will be carried out in regional focus areas, in collaboration with the other Themes and collaborating institutions of CCAFS. In addition to the literature reviews, integrated analyses and case studies, a series of workshops will be organised to evaluate the findings and their implications for efforts to address climate change and food security.

3.3.4. Expected outcomes

CCAFS will contribute to an improved understanding of the ways that different forms of knowledge interact, in particular how and why they influence the capacity to respond to a complex issue, such as climate change. The

research will help farmers, communities, policy makers and many other stakeholders to cope with current climate variability and extreme events, as well as to adapt to the uncertain dynamic and changing conditions of the future. At the same time, it will help researchers to identify and understand the information needs of farmers, as well as the social and cultural challenges of responding to climate change. This is essential for building livelihood resilience and enhancing food security in a changing world.

Specific outcomes include:

- An improved understanding of what information barriers are faced by different groups of stakeholders and what research can contribute in overcoming these barriers.
- Empowerment of stakeholders as agents of change in relation to vulnerability reduction and climate change mitigation and adaptation.
- A shift towards proactive adaptation rather than pursuing a continual process of coping.
- Improved operational protocols for integrating information into decision-making.

3.4. Theme 4: Adaptation pathways based on managing current climate risk

This Theme brings promising innovations in climate risk management to bear on the challenge of protecting and enhancing food security and rural livelihoods in the face of a variable and changing climate.

Long-term climate change occupies the ultimate position at the end of a continuum of time scales at which the climate varies and impacts agricultural systems and their natural resource base. Many of the projected impacts of climate change are amplifications of the substantial challenges that climate variability already imposes on these systems. This is particularly true for smallholder rainfed farming systems in the drier (i.e. sub-humid to arid) tropics – among the human systems most vulnerable to projected climate change (Parry et al., 2005; Easterling et al., 2007), but also for a range of natural resource-based rural livelihood systems. The damage of uninsured climate shocks, such as droughts or floods, to health, productive assets and infrastructure can affect livelihoods long after the stress has ceased (Dercon, 2004; McPeak and Barrett, 2001). Climate variability and the conservative strategies that risk-averse decision makers employ *ex-ante* is one of several factors that contribute to the existence and persistence of poverty – sacrificing appropriate investment, intensification and adoption of innovation in climatically favourable seasons to protect against the threat of shocks (reviewed in Barrett et al., 2007; Hansen et al., 2007). Limited empirical evidence suggests that the cost of climate risk in rainfed farming systems can be quite large, and is borne disproportionately by the relatively poor (Rosenzweig and Binswanger, 1993; Zimmerman and Carter, 2003). Without effective intervention, projected increases in climate variability can be expected to intensify the cycle of poverty, natural resource degradation, vulnerability and dependence on external assistance. Managing current climate risk must therefore be integral to a comprehensive strategy for adapting agriculture and food systems to a changing climate. Given pressing current development challenges and a 2015 deadline for the MDG targets, management of current climate risk offers attractive win–win opportunities for developing countries to contribute to legitimate, immediate priorities while reducing vulnerability to a changing climate.

Climate risk management (CRM) is emerging as a promising framework for engaging climate in development. CRM includes the systematic use of climate information in planning and decision making, climate-informed technologies that reduce vulnerability to climate variability, and climate-informed policy and market-based interventions that transfer risk from vulnerable rural populations. It requires serious attention to the policy and institutional environment in which information is used and adaptations are made. CRM aims to address the full range of variability, balancing protection against the impacts of climate-related hazards with effort to capitalise on opportunities arising from average and favourable climatic seasons. This theme addresses promising innovations in climate risk management that complement ongoing CGIAR work on climate-resilient production technology and market interventions, but that have not yet been fully exploited.

Where they are skilful, seasonal climate predictions appear to offer substantial potential to improve risk management, but they seldom reach poor smallholder farmers in a useable form within a comprehensive package of information and support (Vogel and O'Brien, 2006; Hansen et al., 2006; Patt et al., 2007; Hansen et al., 2007). A better use of historic and monitored climate data combined with agricultural simulation models permits the *ex-ante* quantification of climate-induced risk needed to target innovations that have a high probability of success. Index-based insurance and other financial risk transfer innovations overcome long-standing implementation obstacles associated with asymmetric information, and show promise for addressing risk-related constraints to rural poverty reduction and food security. Index-based insurance and related financial risk transfer products are, therefore, experiencing a rapid resurgence of interest as a climate risk management and poverty reduction tool, but still face important knowledge gaps (Skees et al., 2005; Barrett et al., 2007). There is also substantial scope for using climate information to better manage grain storage, trade and distribution (e.g., Arndt and Bacou, 2002; Hill et al., 2004), and better target external assistance within emerging food crises (Haile, 2005). Research will address critical knowledge gaps related to: targeting, package design, institutional challenges to implementation at scale, managing basis risk and the implications of advance information. A key feature of the approaches reviewed here is the need for immediate investment in resources to test,

improve and refine them. The research set out in this Theme aims to achieve this.

3.4.1. Research questions

1. What are the most effective design and delivery mechanisms for rural climate information products and services that support risk management at a local scale; and what new institutional arrangements and policy interventions are needed to accomplish this?
2. How and under what circumstances can seasonal climate prediction be successfully employed to adopt innovation during climatically favourable seasons; to protect productive assets through more effective, proactive coping strategies in adverse seasons; and to capitalise on market opportunities linked to climate variations?
3. What are the options for diversification at field, farm and regional market scales to reduce food security and livelihood risk and hence reduce vulnerability to climate variability? From the standpoint of risk and vulnerability, what is the optimal activity portfolio in a given context?
4. How can innovative financial risk transfer products (e.g., index-based insurance, derivatives, insured credit) be best targeted and implemented to reduce vulnerability to climate shocks and to alleviate climate risk-related constraints to improved rural livelihoods?
5. What are the options for managing climate impacts on food security and livelihoods at a regional scale through climate-informed strategic grain reserves, trade, distribution and food crisis response; and how are they best implemented and evaluated?

3.4.2. Activities

- Analyse existing institutional delivery systems and bottlenecks for agricultural and climate information (with Theme 3).
- Conduct institutional analysis and equilibrium modelling of climate risk management opportunities through food distribution, storage, trade and crisis response (with Themes 1, 2).
- Conduct local-scale participatory research on climate information products and communication processes, and assess the use and impact of the information (with Theme 3).
- Design and assess the climate resilience of improved crop and livelihood diversification strategies (with Theme 1).
- Research on targeting, implementation and impacts of financial risk transfer products.

3.4.3. Methods

Rural climate information services: Participatory research will develop, assess and refine information products, communication protocols and training curricula for agricultural extension and other intermediaries. At the institutional level, research will include analysis of communication pathways and bottlenecks and alternative delivery systems (e.g. extension, media, group communication processes).

Use and impacts of seasonal climate predictions: Evaluation will integrate survey work, experimental economics, on-farm experimentation and monitoring and bio-economic modelling of management responses to information. The work will also assess historic and monitored climate information, value-added climate information products (e.g. soil water balance, crop yield, disease and pest risk) and alterative delivery mechanisms.

Livelihood diversification: Research will target two levels of risk reduction. Production risk reduction efforts will focus on mixes of cultivars that differ in their phenology, or degree or mechanism of tolerance to environmental stresses, and will combine crop model-based risk analysis, analysis of existing variety data, and experimental (primarily on-farm) research. At the farm and community scales, research on diversified livelihood strategies for reducing income and food insecurity risk will integrate bio-economic modelling and farmer participatory research. Multi-agent modelling is a promising approach for integrating the various livelihood components particularly at the community level.

Financial risk transfer products and services: Research will address: targeting, contract and package design, challenges associated with implementation at scale, management of basis risk, and implications of seasonal forecasts and climate change projections. Methods, including empirical climate analysis, theoretical and numerical economic modelling, surveys and experimental economics, will be employed within a range of implementation pilot projects.

Managing risk through food distribution, storage, trade and crisis response: Research will include scenario analysis within an economic equilibrium framework to estimate market response and welfare distribution, incorporating the spatial effects associated with transportation costs and barriers to trade. Existing climate-informed food security early warning tools will be assessed and enhanced to inform food system management. Modelling will be integrated and ground-truthed with stakeholder participation and survey-based institutional analysis within the food system.

3.4.4. Expected outcomes

- Climate risk management incorporated into regional agricultural development strategies and agendas of NARES and other relevant institutions (e.g., regional climate centres, national meteorological services, universities) in and beyond target regions.
- Effective rural climate information services initiated, supported and evaluated in target regions.
- Enhanced participation of financial market institutions in pro-poor, adaptive, climate-informed services in target regions.
- Enhanced, climate-informed management of food storage, trade and delivery for food and livelihood

security in target regions.

- Systematic technical and policy support for increasingly diversified farming systems and rural economies that buffer against climate shocks and enhance livelihood resilience.
- Establishment of platforms for high-level coordination of climate information services, agricultural development and disaster (e.g. food crisis) early warning and response organisations.

3.5. Theme 5: Adaptation pathways under progressive climate change

This Theme will develop, test and implement adaptation options for maintaining food security in the face of climate change effects projected over the next decades. Strengthening the adaptive capacities of farmers and other land users will encompass technical innovations, such as improved germplasm for climate-related stresses, integrated NRM practices, diversification of production systems, enhanced biodiversity at landscape level and improved institutional settings.

Future farming and food systems will have to be better adapted to a range of abiotic and biotic stresses to cope with the direct and indirect consequences of a progressively changing climate, e.g. higher temperatures, altered precipitation patterns, rising sea levels. Germplasm improvement, improved crop, livestock, aquaculture and natural resource management and enhanced agro-biodiversity have proven track records of decreasing susceptibility to individual stresses, and will offer increasingly important solutions for adapting to progressive climate change (Jackson et al., 2007). However, technical innovations will not be sufficient on their own. Strengthening the adaptive capacities of farmers and other land users requires a variety of strategies ranging from diversification of production systems to improved institutional settings. Adaptive management to continually refine these strategies will be required, and can be supported by the predictive capacity of downscaled global climate models, e.g. forecasts on precipitation, coupled with more effective communication with end users.

It is crucial to add value to ongoing and planned CGIAR investment in agronomic solutions found in crop management and germplasm improvements by integrating them at landscape level with adaptation options in the policy domain. This will develop the holistic management options that farmers and other resources users will require. To this end, CCAFS will initiate a joint working group with institutions engaged in plant breeding, e.g. the Generation CP (GCP) and commodity-based CGIAR Centers, which will advise on the necessary genetic enhancement of principal food crops with regard to the multiple stresses brought about by climate change.

Intensively managed cropping systems offer a variety of entry points to adjust to projected climate change (Aggarwal and Mall, 2002; Easterling et al., 2007; Butt et al., 2005; Travasso et al., 2006; Challinor et al., 2007, Howden et al., 2007). Breeding and marker-assisted selection have been important mechanisms for achieving yield improvements for most crops as long as suitable mega-varieties are available that can be used for introgressing improved genes (Bennett, 2003). In terms of natural resource management, conservation agriculture offers resource-poor farmers a set of possible options to cope with and adapt to climate change (Thomas et al. 2007). Improved water management will represent the key adaptation strategy in both irrigated and dryland agriculture. Emphasis will also be given to crop production systems located in the delta regions, e.g. IGP mega-deltas, to sustain high production potentials under sea level rise (Wassmann and Dobermann, 2007).

Adaptation for livestock production include a variety of management options ranging from adjusted stocking rates to supplementary feeds (Adger et al., 2003, Howden et al. 2007). For pastoralists, however, adaptation options are very limited and mobility remains an important strategy to cope with current climate variability. This will remain an important feature in the future (Oba, 2001), although mobility in many places may suffer because of external pressures, such as population increase. Aquaculture is an important food source in many developing countries and may become even more important as a means of improving food security in response to progressive climate change (Allison et al., 2007).

Several adaptation strategies have been suggested for managed forests, but large areas of forests in developing countries receive minimal direct human management, which limits adaptation opportunities (FAO, 2000). Even in more intensively managed forests where adaptation activities may be more feasible the long time-lags between planting and harvesting trees will complicate decisions, as adaptation may take place at multiple times during a forestry rotation (IPCC-WGII 2007).

A more holistic approach to adaptation to progressive climate change needs to be developed, which considers the interactions of different technical and policy sectors (including management innovation that increase diversification). This would allow for the development of adaptation options that go beyond sector specific management and lead to more systemic changes in resource management and allocation, such as targeted diversification of production systems and livelihoods (Howden et al., 2007).

3.5.1. Research questions

1. What are the most promising measures in natural resources management, agricultural systems management and germplasm development to minimise farmers' vulnerability to climate change in different regions?
2. How can downscaled, GCM-based, near-term (i.e., 1-2 decades) information be incorporated into the design of location-specific adaptation strategies that are robust across the range of possible climate realisations?
3. How can climate-driven shifts in the geographical domains of crop cultivars, crop wild relatives, pests and diseases and beneficial soil biota be anticipated and best managed to protect food security, rural livelihoods and ecosystem services?
4. Given a rapidly changing environment of non-climatic drivers, what is the best approach for integrating individual technological, biodiversity management, livelihood, market adaptation and policy options into comprehensive local-level adaptation packages that exploit synergies, minimise unintended tradeoffs and can readily be adjusted over time; and for accelerating their uptake?

3.5.2. Activities

1. Analyse current scientific knowledge about crop, nutrient, livestock, aquaculture, land and water management strategies successfully applied in areas suffering climate conditions equal or close to those predicted by GCM projections.
2. Utilise down-scaled, probabilistic climate information within an integrated bio-economic modelling framework for fusing 'component solutions' (from pilot testing) into comprehensive adaptation packages in the target regions.
3. Model the range of likely climate-driven shifts in adaptation zones and identify and assess options for managing potential shifts for priority cultivars, production systems, biodiversity resources, and pest and disease threats.
4. Contribute with plant-breeding institutions (such as the GCP and commodity-based CGIAR Centers), to joint research planning of the genetic enhancement of principal food crops for target regions to projected climate change stresses.

3.5.3. Methods

Meta-analysis of previous and newly initiated multi-location trials: This analysis will improve understanding of the climate-sensitivity of existing germplasm and technology, tradeoffs between yield potential, mean yields and stability of yields, and the effectiveness of alternative mechanisms of tolerance to stresses in the context of current climate variability. It will inform germplasm and management options for improved resilience to climate stress. While the analysis will capitalise on existing stations of the CGIAR and its partners, the new focus will be providing guidance to the design and implementation of new experiments on those climate risk/change aspects that have not been covered by previous programmes, e.g. multi-stress treatments and alternative management practices that combine mitigation and adaptation strategies. Experimental station networks need to be strengthened through compatible field trials and measurement protocols including characterisation of soil and meteorological parameters. Performance evaluation will take place at crop, cropping system and farming systems levels.

Identifying the most effective options for adaptation: Building on the analytical framework and tools developed in Theme 1, a suite of modelling approaches will be deployed for assessing impacts and identifying the most effective options for adaptation and the climate-induced risk that is associated with such innovations. Emphasis will be on comprehensive strategies that integrate individual technological, livelihood, market and policy adaptation options. At the crop level, yield-quality models and hydrological/soil chemical models currently under improvement to integrate the specific direct and indirect stresses of climate change, will be integrated with bio-economic modelling within a dynamic, stochastic, multiple criteria framework. The validated models will be coupled to GIS data bases comprising detailed surveys of the natural resources in the target regions. To identify adaptation pathways that are robust across the range of possible realisations of climate change, the research will incorporate probabilistic, downscaled climate projections.

Spatial characterisation of environments and climate-driven spatial shifts: Research to anticipate climate-driven spatial shifts will integrate downscaled climate projections with analysis of agro-ecological zones. It will build on and enhance existing tools and data sets used for crop improvement strategy and targeting, seed delivery targeting systems, pest management and wild relative conservation strategies. Well-defined Target Populations of Environments (TPE) can be used to develop management support systems for breeding programmes; close collaboration with the GCP and commodity-based CGIAR Centers will be sought for capitalising on their well-established methodological framework of advanced breeding approaches. Geo-referenced databases of germplasm collections will be used to identify crops and cultivars best suited to predicted conditions based on agro-ecological parameters of their places of origin. Where climate impacts may lead to major land use changes, research will identify and assess options to support the transitions it will impose on farmers and other actors within the food system. Research will include the bio-economic modelling of expected spontaneous changes to agricultural and land use systems in the face of climate change; and study of historical adjustments to various parameters, such as multi-decadal climate variations.

Farmer- and policy-maker participatory research: Participatory research will be undertaken in close collaboration with other Themes, drawing on novel methods and approaches identified from Theme 3. Theme 5 will directly incorporate farmers' and other stakeholders'

perceptions into the design of adaptation options. Participatory work will enable research to identify constraints to adoption, and test alternative delivery mechanisms at a pilot scale. This will be done jointly with Theme 6 as a basis to assess the acceptability and viability of options aiming at both adaptation and mitigation. The analysis of communication pathways and bottlenecks related to climate risk management (supplied by Theme 4) can feed directly into Theme 5 activities as a basis for long-term, climate-informed decision making. This suite of activities and methods are designed to be integrative in nature with other CCAFS activities.

Land use planning tools for diversification of agro-ecosystems: Large-scale land use change is likely during the next few decades, due not only to climate change but also to continued urbanisation, globalisation, population growth and dynamic market forces. Planning horizons can be described for various types of stakeholder groups through interviews and workshops, followed by a sharing of viewpoints across different sectors. Integration of traditional knowledge and local culture will facilitate stakeholder involvement and innovation. Global climate change models can be run for different climate change scenarios and used with GEDIT to involve stakeholders in planning forthcoming mitigation and adaptation strategies. These would seek to diversify options and provide resilience across landscapes, e.g., annual crop diversity, agro-forestry, timber, non-timber forest products, aquaculture, that increase human nutrition, production and livelihood stability and conservation of the natural resource base.

3.5.4. Expected outcomes

- Optimised and sustained food production in response to a changing climate, as a result of proven feasibility and acceptability of biophysical and socioeconomic livelihood strategies.
- Improved networking established between CGIAR Centers and their partners for technology development and testing, updating adaptation strategies and the routine assessment of the livelihood and food insecurity risk implications of agricultural development in the context of a variable and changing climate.
- Improved analytical and community-based methods and protocols applied to adapt to progressive climate change, including methods for early responses to improved long-range climate forecasts.
- Innovative technologies adopted by farmers that use genetically-improved crops and livestock to enable adaptation to and mitigation of the negative impacts of climate change.

3.6. Theme 6: Poverty alleviation through climate change mitigation

This Theme will evaluate the potential of different practices, technologies and policies on mitigating the impacts of agriculture on climate forcing which also contribute to poverty alleviation through enhanced food security and/or livelihoods.

The poor can hardly be held accountable for climate change, but agriculture does contribute considerably to climate forcing by contributing 10–12% of total global anthropogenic emissions of greenhouse gases (Smith et al., 2007). For the non-CO_2 GHGs (principally methane and nitrous oxides), emissions are highest in developing countries and expected to grow rapidly in the coming decades (Verchot, 2007). Niles et al. (2002) identified some 390 million tonne (mt) of potential carbon mitigation from sustainable agricultural practices alone, many of which can enhance productivity on-farm and contribute to poverty alleviation. Furthermore, the pressures for agricultural expansion in many developing countries contribute to carbon emissions through deforestation and unsustainable land management practices, including the practice of slash and burn. Here Niles et al. (2002) flagged a possible 1565 mt of carbon mitigation potential. Incentive based mechanisms, such as the Clean Development Mechanism and the new UN initiative in Reducing Emissions for Deforestation and forest Degradation (REDD), as well as growing voluntary carbon markets, provide opportunities for smallholder farmers to reduce GHG emissions, move to more sustainable land management practices, and, through tapping into these new market opportunities, bolster their food and livelihood security by diversifying income sources. Other opportunities may exist in emerging markets for certified products in the context of their water-use, inorganic inputs and sustainability of practices. The enhanced income from the sale of certified products may lead to improved livelihoods as well as more sustainable practices that lead to more adaptive systems or more efficient use of climate-related resources. Critical evaluations of these win–win situations have been largely neglected by research (Klein et al., 2007) as the adaptation and mitigation communities have tended to operate in isolation.

Mitigating climate change and adapting to it may also be based (in part) on improved nutrient and natural resource management. There are several ways in which improving natural resource management and agricultural systems can contribute climate benefits, while providing benefits to farmers. For example, increasing nitrogen use efficiency and improving fertiliser management can decrease soil nitrous oxide emissions, and represent a reduction in input costs for farmers. The adoption of practices that decrease methane production in livestock often result in better feed

use efficiency. Sequestering carbon in agro-forestry or community forestry offers opportunities to diversify production, ensure wood supply for local use, and develop more sustainable energy supplies for communities.

The identification and promotion of management options would be underpinned by an improved understanding of the impact of agricultural practices and the current agricultural policy framework on climate change. A key element in this will be developing institutions and mechanisms to support sustainable, pro-poor response options to reduce climate impacts from agriculture.

This Theme will explore mitigation synergies with adaptation pathways, identified in Themes 4 and 5, for smallholder farmers with the express objective of reducing the negative impacts of tropical agriculture on the global climate system whilst supporting more sustainable rural livelihoods indirectly through the adoption of improved practices, or directly through the derivation of income from emerging markets for environmental services. Inevitably trade-offs exist between environmental and livelihood benefits, hence this Theme will analyse these trade-offs in detail from a systems perspective (Stoorvogel et al., 2004).

While bio-fuel production offers novel opportunities for poverty alleviation and carbon offsets, the socioeconomic and environmental consequences of potentially large-scale implementation need careful analysis. There is an ongoing controversy about the mitigation potential of bio-fuels, with many groups asserting that bio-fuels for developed country markets emit more fossil fuel CO_2 than they conserve because of the extensive deforestation involved. This will be considered in the early stages y commissioning workshops and strategy papers which will inform CCAFS of possible research opportunities where value can be added to the ongoing debate.

3.6.1. Research questions

1. What is the GHG abatement potential (full net-net GHG accounting) of promising carbon sequestration and non-CO2 GHG emissions reduction technologies and management practices, and what potential do these have for poverty alleviation?
2. What types of policies and institutional arrangements will be most conducive to providing income to small farmers from increasing carbon sequestration on agricultural lands or reducing further carbon emissions from the clearing of natural habitats?
3. What are the trade-offs between payment schemes for environmental services (pro-environment) and food-security at the farm- and regional-levels?
4. To what extent can adaptation options contribute to carbon sequestration and mitigation of GHG emissions?

3.6.2. Activities

- Determine the potential of reduced tillage, agro-forestry, community forestry, residue management, nutrient management, improved feeding practices and other practices to both sequester carbon and/or the reduction of GHG emissions at the landscape-level and the alleviation of poverty.
- Develop and assess systems for GHG monitoring and accounting at the farm and landscape levels.
- Evaluate global and national policies for GHG emission reductions in the context of enabling the improved adaptation of rural communities (with Theme 2).
- Assess tradeoffs between targeted environmental goals of payment schemes and food security and livelihood goals at the local to regional scales (with Themes 1, 2).
- Commission a set of specialist workshops in the early stages of research to determine how best to address the complex GHG mitigation, food security and livelihood issues associated with bio-fuels within CCAFS.

3.6.3. Methods

Carbon sequestration and GHG abatement potential: A set of target practices where CCAFS can contribute to possible win–win outcomes through new partnerships and novel analytical techniques will be identified. These practices may include livestock management, agro-forestry, fertiliser management and reduced tillage, amongst others. For those target practices identified, we will undertake a full GHG emission inventory in the target regions using field studies for validating simulation models. The validated models will be used to identify the mitigation potential of different management options and – in combination with GIS tools – for the up-scaling of GHG source strengths under different agricultural development and climate change scenarios. We will also conduct a full financial and economic analysis of the improved practices and the traditional practices that will be replaced, to assess the tradeoffs for farmers. The impacts of improved practices on other resources will also be evaluated.

Payment schemes for environmental services: Opportunities for diversified incomes from emerging markets for carbon and other environmental services will be evaluated for their potential in reducing climate forcing and enhancing food security and livelihoods. This will include critical analyses of the best means of implementing carbon-based mitigation schemes that provide benefits to small-holder farmers. Novel opportunities for incentive based schemes that reduce negative impacts on the climate system derived from agriculture will also be sought (for example, through conservation agriculture or certification schemes for agricultural produce). These may require new public–private and public–public partnerships, and for promising opportunities pilot schemes will be developed in the priority regions.

A GHG measurement and monitoring system: Amongst the constraints in connecting smallholder farmers to global carbon markets is the issue of monitoring, evaluating and accounting for success at such a local-scale. CCAFS will develop a multi-scale GHG assessment framework using IPCC approaches. This will combine novel remote sensing techniques with the traditional field inventory

measurements into a net-net GHG accounting system. This will allow implementing agencies to provide an accurate accounting of actual project carbon and non-CO_2 GHG dynamics, and report their contribution to corresponding global carbon environmental benefits. The system will be designed to quantify precision and accuracy. The remote sensing technologies and land-based inventory methodologies will be integrated into cost-effective, adaptable tools for use by a wide range of users in developing countries. Applications of these methods will provide pathways for project developers and managers to increase the realisation of those benefits through the stabilisation/increase in carbon stocks and reduced emissions from land-use activities and land cover change.

Policy evaluation: With Themes 2 and 3, a number of regional policy analyses will be commissioned to assess the ability of countries to host carbon sequestration and GHG abatement projects. This will be closely linked to the scenario exercises. Consultation with policy makers will also be undertaken at the outset and as results become available. An analysis of the existing financial mechanisms for carbon trading will also be commissioned to look at the transactions costs and to establish to what extent the rules of the carbon markets preclude the participation of the poor in developing these markets and preclude the participation of developing countries in participating in climate change mitigation.

Trade-off analysis: In many cases a win–win outcome is not feasible, so a central component of this Theme is analysing the trade-offs between positive environmental outcomes and food security and livelihoods. Trade-off analyses will be conducted with Theme 1 to examine the contribution of prospective practices or policies to reduced climate forcing and the food security and livelihood outcomes from the local to the regional scale. This will include economic, social, cultural and biophysical analyses in order to quantify the broader impacts (net-net accounting) and evaluate the environmental and socioeconomic sustainability of potential interventions.

3.6.4. Expected outcomes

- Rural communities better adapted to climate variability and change due to diversified income portfolios derived from payment schemes for environmental services.
- Reduced carbon emissions from rural agricultural lands achieved through payment schemes to farmers for GHG mitigation which maintain or enhance regional and local food security.
- Broad adoption of climate-friendly land management practices contributing to greater adaptive capacity of agricultural systems.
- Policy-makers taking decisions based on accurate information of the impacts that policy options have on GHG mitigation and food security.

3.7. Adaptation research activities

Much of the research under Themes 4–6 will be largely place-based within the focus regions, and are likely to share common research sites and regional infrastructure. Research activities are therefore grouped together below. Wherever feasible, research across Themes will share common benchmark research sites and regional infrastructure. Several preparatory activities will establish the required regional infrastructure for Theme research. These will include: (i) regional focal studies to document what is known about historic and projected climate change impacts, other research and development efforts on potential climate adaptation or risk management interventions, other major drivers of change in agricultural and food systems, significant institutions and relevant policy processes; (ii) selection of case study countries (Eastern and West Africa), benchmark research locations and national and local institutional partners (discussed further in Section 5.1); (iii) inventory, collect and address the quality control of climate data, agro-ecological zoning information systems and other relevant data sets; (iv) preliminary climate analysis (e.g., low-frequency and inter-annual variability, recent trends, seasonal predictability); (v) preparation of near-term climate change projections for benchmark sites, including multi-scale uncertainty analysis and integration with bio-economic modelling tools (with Theme 1).

3.7.1. Establish infrastructure for place-based research

- Conduct regional focal studies to document what is known about historic and projected climate change impacts, other research and development efforts on potential climate adaptation or risk management interventions, other major drivers of change in agricultural and food systems, significant institutions and relevant policy processes.
- Select case study countries (Eastern and West Africa), benchmark research locations and national and local institutional partners.
- Inventory, secure and address the quality of climate data, agro-ecological zoning information systems and other relevant data sets; and conduct a preliminary climate analysis (e.g. low-frequency variability, seasonal predictability).
- Prepare near-term climate change projections for benchmark sites, including multi-scale uncertainty analysis and integration with bio-economic modelling tools.

3.7.2. Implement regional- and national-scale research activities

- Analyse existing institutional delivery systems and bottlenecks for agricultural and climate information.
- Conduct institutional analysis and equilibrium modelling of climate risk management opportunities through food distribution, storage, trade and crisis response.

- Inventory and assess existing germplasm, production and natural resources management (NRM) technology for climate sensitivity, and assess gaps and priorities for future technology development with respect to projected climate change.
- Model the range of likely climate-driven shifts in adaptation zones and identify and assess options for managing potential shifts for priority cultivars, production systems, biodiversity resources, and pest and disease threats.
- Analyse the role of the existing policy and institutional environment on dissemination and uptake of promising adaptation strategies, and identify opportunities for improving uptake.
- Investigate options to enhance the perception, communication and use of probabilistic climate projections.
- Evaluate global and national policies for GHG emission reductions in the context of enabling improved adaptation of rural communities.
- Assess the sequestration potential and economics of promising technologies with potential to reduce GHG emissions.
- Develop and assess systems for GHG monitoring and accounting at farm and landscape levels.

3.7.3. Implement landscape- and local community-scale research activities

- Conduct local-scale participatory research on climate information products and communication processes, and assess the use and impact of the information.
- Design and assess the climate resilience of improved crop and livelihood diversification strategies.
- Research on targeting, implementation and impacts of financial risk transfer products.
- Design and evaluate integrated, local-scale adaptation strategies.
- Assess tradeoffs between targeted environmental goals of payment schemes and food security and livelihood goals.

3.8. Research outputs

CCAFS will deliver methodology outputs (such as databases, diagnostic toolkits, evaluation frameworks) through multi-level research partnerships that range from the international science community (ESSP) to NARS and public-sector service delivery organisations. Developmental outputs, such as adaptation options, will need different types of partnerships and these may include researchers, government development agencies, NGOs and producer associations, private-sector investors and service providers, and other organisations involved in implementing activities on the ground, for example. Policy outputs may be delivered through coalitions of policy partners and decision-makers, researchers, regional information networks, pro-poor civil society organisations and development donors. All of these outputs will have implications for capacity building among development partners (Table 1).

Table 1. Phase 1 Outputs/Milestones	Target date
Theme 1: Diagnosing vulnerability and analysing opportunities	
Integrated assessment framework, toolkit and resultant indicators to enhance capability to assess climate change impacts on agricultural systems and their supporting natural resources, and likely effects of specific adaptation and mitigation options	Framework 2009, toolkit 2010+
Repository of information on vulnerable populations now and in the future, tailored to characterising benchmark sites and scaling up place-based outputs	2009
Coherent set of development scenarios under a changing climate and differing pathways of economic development, used to identify livelihood opportunities and threats regionally	2012
Characterisation data for the regional research sites in the form of a set of baseline indicators that can be used in future years for *ex-post* impact assessment of CCAFS	2009
Set of information products on likely climate change impacts on agricultural systems, and promising adaptation and mitigation options	2013
Theme 2: The role of macro-level policies	
Assessments of interactions between macro-policies, and local adaptation and mitigation options	2012
Comprehensive, searchable, digital library for the macro-policy theme that will integrate key findings, literature, and ideas for scientists and policy makers, tailored to adaptation planning and mainstreaming activities	2013
Policy fora and dialogues that highlight the need to act on the climate challenge without undermining other important rural development and environmental sustainability goals	2009+
Theme 3: Enhancing researcher–stakeholder interactions	
Sustainable adaptation pathways identified in case studies of researcher–stakeholder interaction	2012
Improved communication methods to facilitate agricultural decision making at scales from local to regional, including documented adaptive learning processes	Methods 2010, doc 2013
New approaches for enhancing science–policy dialogues that account for multiple perspectives and dynamic contextual factors, for multiple levels of decision making	2012
Improved tools for integrating policy objectives and climate and environmental issues that are implemented and used	2013+
Theme 4: Adaptation pathways based on managing current climate risk	
Enhanced climate information products, communication protocols, training materials for intermediaries, and institutional delivery mechanisms for rural communities mechanisms for rural communities	2011+
Determinants of use identified and livelihood and food security impacts assessed for climate information products and services in case study locations	2011
Feasibility, effectiveness and acceptability of diversified crop cultivar and rural livelihood portfolios demonstrated, livelihood impacts evaluated	2013
Synthesised knowledge of how to most effectively target and up-scale index-based risk transfer products to protect and enhance rural livelihoods	2011

Table 1. Phase 1 Outputs/Milestones	Target date
Options identified and assessed, and prioritised strategy for managing climate risk through the food storage, trade and distribution system	2011
Early warning systems enhanced and evaluated for managing climate risk through the food storage, trade and distribution system	2012
Theme 5: Adaptation pathways under progressive climate change	
Site-similarity and agro-ecological zone maps for determining best management practices under changed climatic conditions	2011
Suite of new management support tools for integrated natural resource management (crop, nutrient, water and land management) under progressive climate change	2011
Improved models and indicators of crop varietal fit to scenarios of variability and change	2013
Established research network of CGIAR Centers, their partners and other agricultural stakeholders working to better target, develop and update adaptation technologies.	2013
Theme 6: Poverty alleviation through climate mitigation	
Improved understanding of what makes win-win situations for improving rural income and carbon sequestration for given pilot areas	2011
Food-security-proofed payment schemes for environmental services established in pilot sites	2013
Validated simulation models, and cost-effective monitoring and measuring systems for carbon, livelihoods and environmental services	2013
Policy briefs on implications of emerging bio-fuels markets on regional and local food security	2010

4. Contribution to CGIAR Priorities

CGIAR Science Council (2005) sets out 20 research priorities for the CGIAR, organised within five priority areas. Figure 3 maps the key direct and indirect contributions of the six Themes of CCAFS onto these System Priorities. The CCAFS is expected to contribute in various ways to these Priorities, as follows.

Priority area 1, Sustaining biodiversity for current and future generations. The work will indirectly contribute to 1A, *Conservation and characterisation of staple crops;* 1B, *Promoting conservation and characterisation of under-utilised plant genetic resources to increase the income of the poor;* and 1C, *Conservation of indigenous livestock,* mostly via diagnosis and *ex-ante* assessment of the various adaptation pathways and different roles that plants and animals with different characteristics can play in livelihoods, food security and environmental sustainability. In particular, Theme 5 will contribute to this priority area through work on climate-driven shifts in adaptation zones of crop wild relatives.

Priority area 2, Producing more and better food at lower cost through genetic improvements. CCAFS will contribute to this priority area primarily through enhanced climate information and analytical tools and stakeholder interactions to better target the development of appropriate germplasm to achieve these aims in the context of current climate variability and future climate change. It will directly address 2A, *Maintaining and enhancing yields and yield potential of food staples* and 2B, *Tolerance to selected abiotic stresses,* in relation to both long- and short-term adaptation pathways.

Priority area 3, Reducing rural poverty through agricultural diversification and emerging opportunities for high-value commodities and products. CCAFS will contribute to this priority by evaluating and fostering diversified livelihood strategies for managing climate risk. Within this priority area, adaptation pathways are most likely to contribute to 3B, *Income increases from livestock* and 3D, *Sustainable income generation from forests and trees,* in relation to the assessment and implementation of adaptation pathway options that can benefit livelihoods.

Priority area 4, Poverty alleviation and sustainable management of water, land and forest resources. The CCAFS will directly address 4A, *Integrated land, water and forest management at landscape level,* and 4C, *Improving water productivity* – the former, in particular, is a cross-cutting research area for all the themes of CCAFS. CCAFS will contribute to 4D, *Sustainable agro-ecological intensification in low- and high-potential areas* by exploring the potential to reduce dependence on rainfed subsistence cereal-based agriculture, which is highly sensitive to climate shocks, and by addressing climate risk as a disincentive to the adoption of innovation and appropriate intensification.

Priority area 5, Improving policies and facilitating institutional innovation to support sustainable reduction of poverty and hunger. A key feature of CCAFS is the integration of policy work and stakeholder interactions and it will contribute to 5A, *Science and technology policies and institutions;* to 5B, *Making international and domestic markets work for the poor;* to 5C, *Rural institutions and their governance;* and to 5D, *Improving research and development options to reduce rural poverty and vulnerability,* in relation to system characterisation and the policy and institutional context within which adaptation pathways will need to be implemented.

Priority Area 1	Priority Area 2	Priority Area 3	Priority Area 4	Priority Area 5
Sustaining biodiversity	**Genetic improvements**	**Diversification and high value commodities**	**Integrated NR management**	**Policies and institutional innovation**
1A: Conservation of PGR for food and agriculture	2A: Maintaining and enhancing yield of staples	3A: Income increases from fruit and vegetables	4A: Integrated land, water, forest management at landscape level	5A: Income increases from fruit and vegetables
1B: Promoting conservation/ characterisation of UPGR for income	2B: Tolerance to abiotic stresses	3B: Income increases from livestock	4B: Sustaining aquatic ecosystems for food and livelihood	5B: Making international and domestic markets work for the poor
1C: Conservation of indigenous livestock	2C: Enhancing nutritional quality and safety	3C: Enhancing incomes through production of fish and aquaculture	4C: Improving water productivity	5C: Rural institutions and their governance
1D: Conservation of aquatic animal genetic resources	2D: Genetic enhancement of high value species	3D: Sustainable income from forests and trees	4D: Agro-ecological intensification in low-/high- potential areas	5D: Improving research and development options to reduce rural poverty and vulnerability

- 1 Diagnosing vulnerability
- 2 Unlocking the potential of macro-level policies
- 3 Enhancing researcher–stakeholder interactions
- 4 Adaptation pathways: current climate risk
- 5 Adaptation pathways: progressive climate change
- 6 Emerging mitigation options

Figure 3. Contribution of CCAFS to the CGIAR System Priorities, by Theme. Examples of direct (circles) and indirect (semicircles) contributions.

5. Implementation

The design of CCAFS is based on six Science Themes to be researched collaboratively by CGIAR-NARS-ESSP teams working closely with their respective partners and with stakeholders. The Themes will be primarily researched in a number of regions (see 5.1.1), but there will also be aspects of a more generic nature which are not place-based. Work will combine across questions and with other Themes where possible, and will integrate modelling, empirical and participatory research. Research outputs will be *integrated across Themes within regions* to provide regional public goods (RPGs) and other benefits to the given region. Research outputs will be *integrated across regions within Themes* to provide generic understanding and other IPG based on hypothesis testing and methodological development in a range of environments. Research within the Themes will be jointly designed by members from both research and policy communities so as to (i) maximise benefits to regional/national policy formulation by addressing issues co-defined by regional and national stakeholders; (ii) help transform the research agenda to more effectively deliver the information needs for improved food security policy formulation; and (iii) raise awareness of climate change issues amongst agricultural and food policy makers and resource managers. Place-based research will be undertaken at several spatial levels within the target regions, and will share common research sites and infrastructure where appropriate. However, the outputs will be IPG with utility well beyond the research locations.

5.1. Theme science delivery

Research on each Science Theme will be coordinated by a Theme Leader who will be responsible for designing and initiating research activities, and who will also devote substantial time to direct involvement in research activities within their respective Theme. In the early stages of CCAFS, commissioned research will be the primary mechanism for addressing the research questions.

Commissioned research projects may address combinations of thematic research questions in particular locations, or topics (e.g., bio-fuels) which span regions. Decisions about the scope of research projects and the teams involved will be the responsibility of the Steering Committee, in close consultation with the Management Team (see Section 6). Commissioned research is particularly needed in the early stages to establish CCAFS's core partnerships and regional research infrastructure, and to map out detailed research agendas.

As CCAFS develops, and likely towards the end of Phase 1, CCAFS will also launch competitive open calls as appropriate. This mode of working has the advantages of opening the agenda to a wider group and attracting the best advanced research, but at the expense of considerable transaction costs. Competitive calls will be highly specific so as to minimise off-target proposals.

Several aspects of the research, especially in Themes 1–3, will be of a generic nature, and will need to draw on data and skills worldwide. Studies that are not place-based will necessitate the creation of time-bound, specialist Working Groups (e.g. on bio-fuels). Some aspects of Theme 4–6 research will also need to draw on experiences from outside the initial focus regions, and a budget is also earmarked for expert consultations, workshops and literature syntheses. The global challenge that CCAFS addresses, and the research agenda to address the challenge, are defined by the Research Themes. Many of the thematic research questions, however, and particularly those involving the development, demonstration and evaluation of adaptation and mitigation pathways (Themes 4–6), can only be addressed in particular agro-ecological and socioeconomic contexts. Work within multiple focus regions is a way to implement the research agenda across Themes, and will be synthesised across regions leading to IPG. Much of the research, and especially that in Themes 4–6, will be conducted in the focus regions by teams representing CGIAR, ESSP, NARS, and potentially other ARIs and relevant partners with particular expertise in the given region. Theme Leaders and the Director will share responsibility for ensuring that work across Themes and across regions is synthesised to produce IPG and RPG, thereby limiting the risk of individual Themes developing independently of the whole.

5.1.1. Focus regions

While there are many regions in the developing world that warrant research investment in relation to climate change, agriculture and food security, CCAFS should not attempt to over-stretch in the initial years. It is crucial to establish and demonstrate the efficacy of approach and method in a small number of regions in the first instance and then consider expansion in relation to science need and financial capability.

The three initial focus regions are Eastern Africa, West Africa and the Indo-Gangetic Plains (Box 4). Within both Eastern and West Africa, large rural populations who depend on rain-fed, cereal-based subsistence agriculture or on pastoralism in the drylands (i.e., sub-humid to arid) are highly vulnerable to climate variability and sensitive to any future changes in the climate. With increasing frequency and severity, episodic climate shocks – primarily drought – have led to major food crises in the semi-arid and arid zones of both regions, with resultant loss of life and livelihoods, and a cycle of costly disaster relief

competing with long-term development for scarce resources.

The climate of West Africa is characterised by a strong latitudinal rainfall gradient that determines cropping systems, and by dramatic fluctuations in the rainfall regime at multi-decadal time scales. These amplify the substantial year-to-year rainfall variability, and provide an opportunity to look historically at climate-driven shifts in crop adaptation and at past adaptations to changes in rainfall regime (Theme 5). The region suffers from widespread land degradation particularly in the semi-arid Sudano-Sahelian zone, but benefits from policy support for regional drought management, and for intra-regional trade supported by a common currency across the Francophone countries. In contrast, Eastern Africa exhibits strong spatial heterogeneity of climate, topography, agro-ecosystems, livelihoods and environmental challenges. Temperature gradients associated with elevation often delimit subsistence agriculture and higher-value horticultural and plantation agriculture. Rainfall predictability at a seasonal lead time is relatively high in Eastern Africa, providing opportunity to support risk management (Theme 4).

Intensified, irrigated agricultural production systems dominate the IGP. With a longitudinal rainfall gradient, the IGP is prone to both drought toward the west, and flooding and saltwater intrusion toward the east. The dominant wheat and rice crops are sensitive to increasing heat stress associated with climate change. Through a combination of mechanisms (increasing evapotranspiration, melting glaciers, changing rainfall, etc.), climate change is intensifying the stress on surface water and groundwater resources that are already facing overexploitation and pollution.

While drought is clearly a major threat for many parts of Africa, CCAFS must take a holistic view of changing climate, as wetter conditions, if too wet, may be equally problematic. In areas that become more favourably wet, there is a need to maximise the opportunities that climate change will bring. The three proposed regions offer the range of anticipated conditions to allow CCAFS to take the necessarily broad view. Criteria for selecting the initial focus regions were:

- Poverty and vulnerability – high degree of vulnerability to climate, large poor and vulnerable populations, drivers of vulnerability that extend beyond the focus region.
- Complementary set of social, cultural and institutional contexts.
- Complementary climatic contexts, with different temporal and spatial scales of climate variability and degrees of predictability.
- Significant, but contrasting climate-related problems and opportunities for intervention.
- Security, governance and institutional capacity that favour the likelihood of generating transferable results.

Box 4. Selection of focus regions

The IPCC (2007) identified South Asia and Africa as being particularly vulnerable to climate change and deserving of priority attention. Thus, the process of selecting the initial focus regions began with six candidates: South-East Asia, the Indo-Gangetic Plains (IGP), Northern Africa, West Africa, Eastern Africa, and Southern Africa. The decision to select three initial focus regions reflected a balance between two competing considerations: (i) working across contexts that are sufficiently heterogeneous to ensure that outputs and outcomes of place-based research have global relevance, and (ii) ensuring that sufficient resources are brought to bear to address the deliberately complex problems that CCAFS poses. A number of reports were consulted to provide the basis for prioritising these regions (IPCC, 2007; UNEP, 2007; IFRC World Disasters Reports; EM-DAT; UNDP, 2007).

All six candidate regions suffer major hydro-meteorological shocks, and confront significant, climate-related environmental problems. The initial selection process sought to sample across these different challenges. The IGP is prone to drought, to flooding associated with cyclonic storms and is at risk from sea-level rise. While all four African regions are drought-prone, Eastern and Southern Africa are also prone to flooding. Environmental degradation is largely driven by population pressure and the resulting over-exploitation and pollution in the candidate regions in Asia, and by several drivers of land degradation in Africa.

Northern Africa was given lower priority in the first instance because of its limited geographical area, lower population density in rural areas, relatively low poverty rates and the unique characteristics of the agricultural environment that limit transferability of results. Similarly, Southeast Asia was given low initial priority because it experiences less water stress than the other regions, it is making good progress toward food security goals and because remaining food insecurity is less driven by climate than in the other candidate regions.

Eastern, West and Southern Africa share high rural poverty rates and large populations that depend on rainfed subsistence agriculture in drylands. Among the three regions, Eastern and West Africa have stronger regional climate institutions and processes that can support climate information for adaptation (Theme 4), a greater CGIAR presence and stronger sub-regional agricultural organisations. In contrast, Southern Africa already has relatively good systems in place to manage water resources. Countries in Southern Africa are also making somewhat better progress than Eastern or West Africa toward food security goals. Among these three African regions, Western and Eastern Africa present the best opportunity for synergistic research with the potential for both immediate regional benefits and transferability beyond the regions.

Projected future climate change was not considered a strong discriminator among candidate regions, as all regions are expected to warm, future rainfall trends are subject to considerable uncertainty, and changes in

Box 4. continued...

climate statistics are unlikely to be detectable over the ten years of CCAFS. The initial focus regions span areas with evidence of both future drying (IGP?) and wetting (Eastern Africa) trends, as adapting to climate change is about capitalising on opportunities as much as minimising negative impacts.

The Steering Committee, in consultation with the Management Team and relevant regional stakeholders (via the Stakeholder Platform), will determine whether and when to extend CCAFS's work into other focus regions, in the context of developing the science programme and funding opportunities. Southern Africa is a possible candidate (Lobell et al., 2008), and areas of Latin America/Caribbean might also be considered, especially within the context of Theme 6 where significant mitigation gains exist, and/or sea-level rise is a major threat, However, new fully-fledged focus regions will probably not be added during the first two to three years while work is being established in the initial set of focus regions. The decision will consider the same criteria used to prioritise the initial focus regions, and will be informed by:

- Availability of sufficient financial and human resources to expand the geographic focus without compromising the ability to deliver the research outputs and objectives.
- A scoping study to synthesise what is known about vulnerability, potential adaptation and mitigation options, ongoing activities aligned with the CCAFS goal and objectives and institutional capacity.

5.1.2. Benchmark sites within focus regions

Research within the focus regions will target scales ranging from the field to sub-regions. Research that must be addressed at the field, farm and community scales in each region will be conducted across a set of research locations representing relevant biophysical and socio-economic gradients. These 'benchmark sites' will be selected by a regional science/stakeholder group coordinated by the CCAFS Regional Facilitator based in a CGIAR regional office, and in close consultation with Theme Leaders. A key aspect will be to build on ongoing CGIAR and national research infrastructure and research sites, and existing data, rather than establishing CCAFS research sites de novo. The spatial scale of the sites needs to be established based on ongoing studies, providing these are suitable for addressing Theme questions. Discussion with regional coordination groups is therefore key to identifying optimal research sites. Two main selection criteria could be considered, depending on detailed research planning:

- Lie along gradients of anticipated temperature and precipitation change and current and anticipated land use pressure.
- Represent different institutional (e.g. land tenure) arrangements.

In West and Eastern Africa these will be selected by the regional coordinating group, in consultation with national agencies. In the IGP CCAFS will initially adopt the set of five sites (districts) where collaborative CGIAR–ESSP research is already underway within the ESSP–GECAFS project (Figure 4).

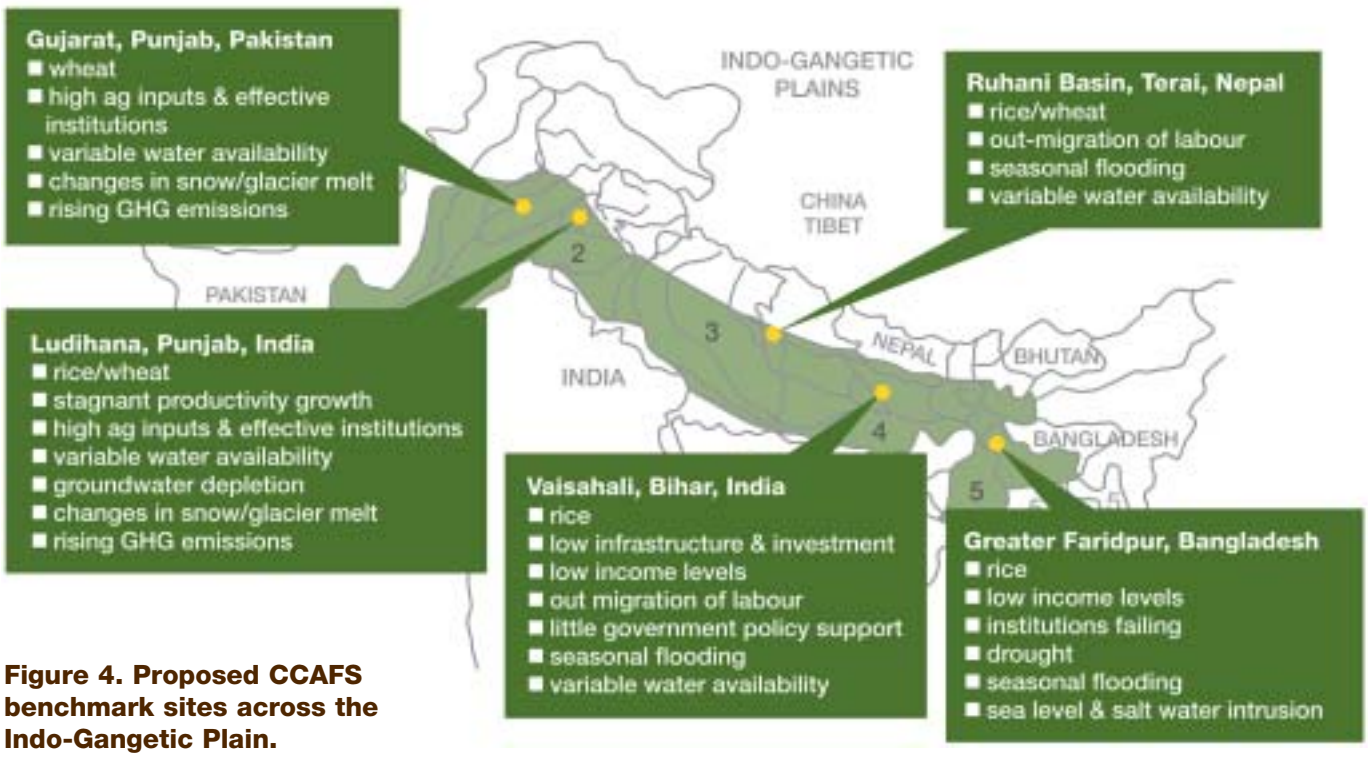

Figure 4. Proposed CCAFS benchmark sites across the Indo-Gangetic Plain.

5.1.3. Within-region and between-region integration

An important aspect of CCAFS is to have impact within the initial focus regions. The benchmark site approach will provide outputs, outcomes and impacts for the given sites, but – in that these will be chosen to be representative of the region as a whole – a specific integration approach is needed which places case study research in the regional context. Using standard characterisation techniques at a number of sites across the study regions allows commonalities and differences, and trends or gradients, in agricultural and food systems to be identified. Their vulnerability to climate could be assessed along the gradient resulting in a set of parameters which collectively describe the links between agricultural and food systems and, for example, water stress for the region as a whole. Another advantage of the case study approach is that analyses can determine the presence or absence of connections among the case studies and evaluate their importance to the food systems. This will help in understanding the utility of a regional-scale evaluation of non-environmental resources, such as labour and strategic food reserves.

Local-level questions (researched in case-studies at the sub-regional level) will be linked to regional-level questions (which relate to the region as a whole – a top-down view of the region) by a set of cross-level questions, which integrate the output from case studies up to the regional level (bottom-up view of the region). Launch workshops in each region will define the specific information needs, identify case-study sites and establish inaugural research teams.

Between-region integration will come about by Theme-level workshops and integration activities examining hypotheses, and testing the robustness of methods and concepts across the range of contrasting environments represented by the initial (and then further) regions.

5.1.4. Extrapolation beyond focus regions

All CCAFS Themes address generic issues and will develop tools that are relevant beyond the scope of the initial target regions. The selected regions encompass numerous biophysical and socioeconomic characteristics of climate change effects that are analogous to other regions of the developing world. Likewise, the scenarios (see below) incorporate universal response pathways and, thus, could be used as prototypes within other regional contexts. Modelling tools can be validated and used for other areas as well as for up-scaling of, for example, food production and GHG emissions.

5.2. Cross-CCAFS activities

5.2.1. Scenario development

Identifying viable technological and policy options to improve food security in the face of climate and other environmental changes requires improved dialogue between researchers, the policy process and resource managers. This is particularly important at the regional level where many regional policy options arise, supported by technical interventions. Scenario analyses conducted at regional level help systematically explore such options at the appropriate scale by providing a suitable framework for (i) raising awareness of key environmental and policy concerns, (ii) discussing viable adaptation options, and (iii) analysing the possible consequences of different adoption options for food security and environmental goals. These can be based on scenarios developed at the global scale (e.g. Millennium Ecosystems Assessment, UNEP-GEO), but such analyses do not necessarily feature issues that are of particular relevance at the given regional level. Further, they do not necessarily address all the issues related to agriculture and food security. CCAFS will lead a set of integrated scenarios for each region to help tie together CCAFS Themes as well as deliver policy-relevant outputs specifically tailored for regional conditions and issues. These will form an important aspect of communications and capacity building and will help build regional science–policy teams who can take forward CCAFS outputs. Scenario exercises will build relationships with a variety of stakeholders with divergent and varied perspectives and a robust, yet flexible, process for planning under uncertainty over time and in the context of change.

The scenario development process will be based on a number of steps:

1. Identifying key regional climate and policy issues, based on an initial stakeholder consultation workshop involving regional scientists and policymakers.
2. Drafting outlines for a set of four prototype scenarios in a first regional workshop, to be further elaborated upon in a follow-up writing exercise by regional authors. These regional scenarios could be based on a set of global scenarios (e.g. MA, 2005), but will allow for regional deviation where needed.
3. Describing developments per scenario for key aspects of the regions' agricultural and food systems.
4. Systematically assessing agricultural and food security developments per scenario based on adaptation and mitigation pathways.
5. Discussing and mapping out a first indication of which response options and adaptation strategies might be conceivable and viable to best strengthen regional food security under the four scenarios.

Scenarios will be developed for each region based on existing work; for example, the MA (2005) outlines four

developmental pathways characterised by specific population growth rates and levels of economic development (among other things), corresponding emission scenarios of GHGs are outlined in IPCC (2007) and levels of human appropriation of natural resources and ecosystem services. These scenarios can be quantified using a broad suite of existing models that project land-use changes, changes in food and feed demand, changes in water use, and changes in agricultural production. Scenario analysis should allow for characterisation of development pathways in the study regions that should be able to achieve development objectives and the goals of CCAFS. Work will be coordinated by a CCAFS Scenarios Science Officer who will lead scenario development in each region and who will integrate results across regions to inform global-level scenarios. The scenarios component will be undertaken in collaboration with a ESSP-GECAFS multi-site scenarios study currently being discussed with the Bill and Melinda Gates Foundation and the Global Environment Facility.

5.2.2. Theme integration

The six Research Themes are interdependent. For example, the adaptation set (Themes 4–6) depends on tools, methods and knowledge outputs developed in Themes 1–3. Several cross-Theme research activities have been identified. Wherever feasible, Themes 4–6 will share common benchmark sites and regional research infrastructure. The Management Team will consider opportunities for synergies across Themes as they determine the scope of commissioned and competitive research projects. They will also share responsibility to ensure that work within Themes is coordinated and synthesised across CCAFS, and produces IPG. Annual CCAFS synthesis workshops will be held immediately following a set of Theme synthesis workshops (to be held concurrently) to recap, distil and create new value-added from research activities within each Theme, and to synthesise knowledge across the Themes. Where feasible, these events will be held in focus regions to both bring in local participation and strengthen S–S partnerships. The Steering Committee, in consultation with the Management Team, may adjust the frequency, scope and venue of the workshops as needed.

5.2.3. Capacity building

Capacity building in both science and policy will be an integral aspect of CCAFS and will cut across all Themes and regional activities. It will encompass S–N, N–S and S–S aspects. Some CCAFS-wide activities, for instance scenario development, offer a powerful capacity-building framework, and in themselves culminate in the establishment of multi-disciplinary science/policy teams who have grown to trust each other and form an effective long-term resource. Capacity building will recognise that CCAFS must not only focus on current science and policy decision-makers, but must also seek to build the capacity of the next generation who will be responsible for action at a time when climate change and its impacts are probably going to be much more evident. In this respect, universities in the south will be important partners, and CCAFS will seek to ensure that advanced climate science is built more strongly into their curricula. In principle, capacity building will be achieved in a number of ways.

Science capacity will be built by:

- Networking scientists across the region and across disciplines to jointly address common research issues.
- Inception workshops run by Theme Leaders and other resource people to bring regional researchers up to date on latest concepts and methods.
- Linking regional researchers with scientists world-wide through the wider CCAFS research agenda, and especially the inter-regional synthesis activities.
- Regional training and dissemination workshops, particularly for NARS affiliated with SROs and for national meteorological services associated with regional climate centres in the focus regions.
- Meetings with regional policy-makers so that the science community is more aware of the key issues facing policy-makers and the constraints under which they have to work.

Policy capacity will be enhanced by:

- Involving regional policy-makers in scenario exercises to raise their awareness of climate change issues and the consequences of given scenarios for development.
- Working with policy-makers to interpret research findings in the context of policy formulation.
- Providing decision support tools to help with analysing trade-offs between socioeconomic and environmental goals for given adaptation options.

A specific outreach and capacity-building training effort will be targeted at young agricultural scientists and policy experts, to ensure adoption to the highest degree of the data and analysis capabilities developed under this CCAFS. An accreditation programme is envisioned to provide standardisation and tracking of policy implementation. This will be linked to the UNFCCC Nairobi Work Plan. This could be developed via links though ESSP-START (the ESSP System for Analysis, Research and Training), thereby building on programmes, such as Assessments of Impacts and Adaptation to Climate Change (AIACC) and Advancing Capacity to Support Climate Change Adaptation (ACCCA).

5.2.4. Information management

CCAFS will produce, integrate and inter-operate data, information and software from geographically dispersed institutions in order to fulfil its objectives. In support of the complex communication, collaboration and integration requirements, web-based collaboration systems are required that are participatory and largely user-driven and user-managed (Web 2.0), employing methodologies and technologies with proven scalability. These online collaboration systems will create a transparent and participatory environment for the efficient and effective

production, integration and inter-operation of the IPG resulting from CCAFS. CCAFS is expected to generate large climate and other primary datasets, especially in Theme 1. Other Themes will however generate more diverse data sets that will be individually valuable, and must be documented and indexed at a metadata level. Secondary use and publication of these datasets as IPG will require coordination and agreement on some standards and quality parameters. Help will be sought from existing data centres (e.g. the World Data Center for Climate or the IRI for climate and environmental data; the Center for International Earth Science Information Network, CIESIN, for agricultural, environmental and socioeconomic data) and Open Content agreements will be established. The Management Team, in consultation with the CGIAR Consortium for Spatial Information, will identify the most appropriate facility (CGIAR Center or ARI laboratory) for establishing and hosting a data management centre of CCAFS and liaising with other data centres.

5.2.5. Communication strategy

This is a cross-CCAFS activity and will be undertaken in close collaboration with the communications team in the CGIAR and Alliance Secretariats. Main elements will include:

- Organising and publicising the launch conference
- Other general awareness-raising events
- Planning and developing a CCAFS website
- Other public awareness activities: building media relations, donor relations, information products for these groups, etc.
- Information products for different target groups for dissemination of results: policy-makers, end users, etc.
- Promoting the scenario exercises within and between regions.

5.3. Partnerships

5.3.1. A new research partnership: CGIAR–ESSP

The CGIAR–ESSP collaboration will go beyond the traditional disciplinary science and allow a truly integrated multi-disciplinary, resilience-based approach to the climate change–food security problem. This means a focus on key drivers, possible non-linear and threshold responses, interactions of biophysical and socio-economic factors across scales, and possible socio-economic responses.

ESSP brings to the table the climate modelling tools for generating future climate scenarios critical for assessing climate change adaptation and mitigation strategies, and broad knowledge and experience in data and models of land use and how land management decisions impact on the Earth system dimensions of climate, water resources, biodiversity and soils. It also brings expertise in remote sensing, bio-geochemical cycles, hydrology, land degradation, function and valuation of biodiversity, and the social and political dimensions of vulnerability and adaptive capacity. The CGIAR complements these strengths with experience of modelling and evaluating how agricultural, forestry and land management options can impact on the livelihood options for poor farmers, herders, fishers and women within a dynamic market and policy environment, and experience in agricultural by-products with potential for bio-energy generation.

Collaboration between the two communities will allow for better climate change projections, including land surface feedbacks on climate particularly in relation to agricultural activities, geographically explicit analysis of potential productivity, tools for full carbon/water/nutrients accounting and valuation of biodiversity and other ecosystem services. It will also identify the situations where both global and local environmental benefits can be attained based on an improved understanding of feedbacks to the Earth system, whilst also generating income and strengthening rural livelihood strategies. It will link available knowledge and skills (e.g. modelling) unique to ESSP regarding global and regional climate change combined with the CGIAR's long-term, on-the-ground expertise in agro-ecosystems of the developing world and large research-for-development networks. It will combine ESSP expertise on agro-biodiversity management (agro-ecosystem services, biodiversity integration, soil biology, conservation agriculture, trade-off valuation - farmer income vs. benefits to society - and participatory approaches) and sustainability assessment (e.g. DIVERSITAS) with CGIAR's 'heartland' research on germplasm banks, genetic enhancement of crops and animals (including fish), integrated pest management and crop–livestock systems.

Box 5 gives a list of current ESSP projects that could link with CCAFS research.

Box 5. ESSP projects that potentially link with CCAFS

Parent	Project	Comment – most immediate link(s) with CCAFS
WCRP-CLIVAR	WGSIP	Theme 4 – note also WGSIP/GEWEX SIP link through TFSP
	WGCM	Theme 5 (possibly also WGNE)
	GSOP	Theme 1 – but general in terms of climate data
	C/P WG	Perhaps a link, although weak, in terms of data
	ECTTDI	General information on detected climate change for all themes
	VACS	As IOP for Africa
WCRP-GEWEX	GLASS	Theme 4 (main contact with WGSIP for TFSP)
	AMMA	For West Africa
	MAHASRI	For Indo-Ganges
	HAP	Theme 4 – water resources prediction
IGBP	AIMES	Themes 4–6
	GLP	General relationship to CCAFS, but especially perhaps Themes 4–6
	PAGES	General data/predictability (see C/P WG)
	The Planet in 2030-2050	Scenarios
IHDP	GECHS	Theme 3
	IT	Particularly its sub-project on FOOD
	LUCC	Joint with IGBP – highly relevant to most Themes
	UGEC	May be relevant if impacts of urbanisation on agriculture are considered
	GLP	Relevant to most Themes
DIVERSITAS	bioGENESIS	Possible links to most Themes
	ecoSERVICES	Possible links to most Themes
	bioSUSTAINABILITY	Possible links to most Themes
	agroBIODIVERSITY	Possible links to most Themes

5.3.2. Strategic regional partnerships

Research will be implemented within strategic partnerships with relevant regional organisations and groups and, through these, with appropriate national institutions (e.g. agriculture research institutions, meteorological services and the university sector). It will integrate issues across levels ranging from region-wide (e.g. climate signal and other Earth system processes, trade policies, labour migration) to national/local (e.g. technical and policy adaptation and mitigation) options. Collaboration will bring together the best agricultural, climate and Earth system science; will critically assess and advance the state of science, methodology and technology; will enhance N–S, S–N and S–S capacity building; and will strengthen science–policy interfaces.

Many potential partners participated in proposal development through a series of workshops and statements of interest from the likely main regional partner organisations were received during the planning phase.

Research in each region will be facilitated by a CCAFS Regional Facilitator to be based in CGIAR institutions with a regional mandate, namely at the offices of the Regional Alliance Collective Action Network in West Africa and in Eastern Africa and at the Rice–Wheat Consortium.

For West Africa, research with national partners will be coordinated by a group involving AGHRYMET, CORAF/WECARD and possibly AMMA, and facilitated by the Regional Facilitator working closely with the Management Team. Other organisations with a regional mandate may be added in due course. For Eastern Africa, research with national partners will similarly be coordinated by a group involving ASARECA and ICPAC, and facilitated by the Regional Facilitator, again working closely with the Management Team. Other organisations with a regional mandate may be added in due course. ACMAD will liaise closely with both West and Eastern Africa coordination groups, and further links will be explored with other regional organisations, including COMESA.

For the IGP, research with national partners will be coordinated by a group involving the Rice–Wheat Consortium (which will bring links to agricultural research institutions in each country) and a leading climate change institute from each country.

In all regions the CGIAR structure for regional coordination will be used to coordinate the collaboration of individual centres. Close liaison with the WFP, FAO and other major international organisations will build links with policy processes at the highest levels both regionally (e.g. with the AU in Africa) and nationally.

5.3.3. Strategic international partnerships

The innovative collaboration between the CGIAR Alliance and the ESSP, and their respective partners, will form the backbone of strategic international partnerships. Several ARIs have expressed an interest in, and have contributed to the development of, this CCAFS. These include the many institutions mentioned in the pre-proposal as well as others, for example, AGROPOLIS. These new partnerships will be established and/or strengthened, capitalising on the innovative agenda. Strategic S–S partnerships will be established based on the opportunities for Theme synthesis across the diversity of research regions.

5.3.4. Links to other Challenge Programs

Links with other CPs will include, *inter alia*: joint characterisation of Target Populations of Environments (TPEs) for targeting germplasm and adapting crop improvement strategies to climate variability and change with Generation CP, and through the establishment of an inter-CP working group advising on methodology; joint water management and5.4. Dissemination and utilisation of resultsnance studies in the Indo-Gangetic Plains with Water and Food CP; and the possibility of sharing research sites with the Sub-Saharan Africa CP.

5.4. Dissemination and utilisation of results

The challenges associated with climate change, agriculture and food security are not related to the distant future, but are of immediate relevance – and will become even more so over the next decade. The results from CCAFS must, therefore, be rapidly and widely disseminated, not only within the academic literature, but also to stakeholders, practitioners, policy-makers and the general public. CCAFS will prioritise dissemination of results through multiple media formats, including research articles and reports, briefings, brochures, internet sites, videos and newspaper and radio stories. The dissemination strategy will take advantage of the extensive dissemination outlets and networks that already exist, for example newsletters of the CGIAR Centers and the ESSP communities (e.g. IHDP Update, IGBP's Global Change Newsletter, DIVERSITAS Newsletter, START, Global Water News, and WCRP News).

Although dissemination of results is important, it is the utilisation of results that will make a difference for food security under climate change. Utilisation will be monitored throughout the project, including through the study of researcher–stakeholder interactions and through regional collaborating institutions. The outcomes of such utilisation will iteratively feed back to the research process and promote both flexible research and policies for adaptive management. A key emphasis of CCAFS is on rapid learning, capacity building and enablement of stakeholders to respond positively to the changes that are expected to influence livelihoods and food security.

5.5. Timeline and milestones

CCAFS has a 10-year timeline:

- Phase 1 (years 1–5): detailed scoping; establishing research teams; building stakeholder communities; reviewing existing preliminary studies; developing initial methodologies; establishing baselines through analyses of current impacts and vulnerabilities; undertaking *ex-ante* assessments of anticipated changes due to CCAFS activities; commissioning initial research on adaptation and mitigation pathways; initial dialogue with the policy community and non-research communities; delivering a detailed work plan for Phase 2.
- Phase 2 (years 6–10): undertaking detailed analyses of adaptation and mitigation pathways; identifying areas of potential benefits from climate change; capacity building for undertaking trade-off analyses and identifying win–win situations; undertaking *ex-post* analyses of performance of CCAFS activities; launching research into additional and/or emerging issues; ensuring capacity is in place to continue research after the end of CCAFS; and enriching the dialogue with the policy community and non-research communities.

Table 1 (Section 3.8) lists Theme outputs with anticipated delivery dates for each to use as milestones.

5.5.1. Launch Conference

CCAFS will be launched with an International Conference in early 2010 to which all proposed regional groups involved in CCAFS will be invited, together with the Steering Committee and Management Team and donors. This will map out the more detailed regional partners at the national level, and will also agree on the first set of research activities to be undertaken both within regions and on generic issues across all Themes. Initial scenarios activities will also be designed.

5.6. Exit strategy and legacy

As further policies are developed in response to new knowledge, insights will be incorporated into the assessment/trade-off tools developed within CCAFS to assist participating policy-makers and stakeholders choose the best mitigation and adaptation policies to enhance food systems and food security, while at the same time minimising negative effects on the environment and ecosystem services. The combined effect, therefore, will be the implementation of comprehensive, cost-effective, responsive and sustainable mitigation and adaptation

strategies. Elevating the trade-off issue and promoting a 'not-only climate change' perspective within the policy community is also anticipated as a major legacy of this part of CCAFS.

The exit strategy will be based on ensuring sustained partnership and capacity at three levels. First, the research collaborations built up over the life of CCAFS will have been consolidated to ensure lasting links are in place; and the dedicated capacity-building activities will give rise to a new generation of scientists around the world able to further mainstream climate science into local and regional policy formulation. Second, through continuing dialogue and targeted capacity-building activities, SROs and regional technical institutions operating within the focus regions will be equipped to continue targeted research and implementation activities beyond CCAFS's project locations. Third, CCAFS will increasingly engage a network of international development organisations that have the mandate and resources to scale-up implementation of the interventions developed and tested within CCAFS.

The CCAFS legacy will therefore be new and better approaches to linking climate and other aspects of Earth system science for agricultural development based on a science agenda driven by the policy need for information.

6. Governance and management

6.1 Steering Committee and Management Team

CCAFS governance and management are designed to address four distinct tasks:

Task 1: Oversee, and make decisions on, science direction and resource allocation, which will be the task of the CCAFS Steering Committee (see below).

Task 2: Implement CCAFS, which will be the task of the CCAFS Management Team (see below).

Task 3: Obtain advice on science direction from stakeholder and maintain their buy-in, which will be achieved through an Advisory/Stakeholder Platform (see below)

Task 4: Maintain links to CGIAR and ESSP agendas by the Chair and/or Director giving updates to the respective annual meetings of the CGIAR Alliance and ESSP Science Committee. This will allow the CGIAR Alliance and ESSP Science Committee to (i) advise on emerging areas of CGIAR and ESSP science; (ii) identify links with new activities; and (iii) provide a conduit to their respective communities.

6.1.1. CCAFS **Steering Committee**

The CCAFS Steering Committee comprises the CCAFS Chair, about 8-10 independent members, and one representative from each of the CGIAR Alliance and the ESSP Scientific Committee (both *ex officio*). The Chair and members will be appointed jointly by the Alliance and the ESSP SC for a period of three years, renewable once. The initial composition (December 2008) of the SC is given in Annex 2. The CCAFS Director shall be invited to attend meetings as an observer. The Steering Committee will meet twice a year (plus teleconferences as needed).

The CCAFS Steering Committee will be led by an independent Chair who will (i) be a highly respected international scientist; (ii) be knowledgeable of either the CGIAR or the ESSP (with a strong familiarity, at least, of the other); (iii) be experienced in 'science for development'; and (iv) have substantial experience in leading complex, collaborative international research endeavours. The Chair position will possibly take 3–4 months duty per year initially (i.e. during the establishment phase), but this is anticipated to reduce to 1–2 months per year as the post adopts more of an oversight role.

The CCAFS Steering Committee will:

(i) approve annual work plans outlining scientific priorities
(ii) approve annual budgets and audited accounts
(iii) oversee the work of, and receive reports from, the Management Team
(iv) link to stakeholders through the Advisory/Stakeholder Platform
(v) report to donors, and
(vi) appoint the CCAFS Director.

Figure 5. Overview of the structure of CCAFS.

6.1.2. Management Team

The CCAFS Director, the six Theme Leaders and a representative from the institution which hosts the Director and the Secretariat of CCAFS form the CCAFS Management Team.

The CCAFS Director will have substantial experience in (i) either the CGIAR or the ESSP (with a strong familiarity, at least, of the other); (ii) 'science for development'; and (iii) managing complex, collaborative, interdisciplinary international research endeavours. The full-time position, to be funded by CCAFS, will be appointed by the Steering Committee as a fixed term position in consultation with the host institution who shall be the employer. Terms and conditions will be based on the host institution. The Director will lead a small (approximately 3 person) secretariat funded by CCAFS with in-kind support.

The Management Team will:

(i) coordinate the overall CCAFS agenda
(ii) design commissioned and competitive research
(iii) help integrate CCAFS activities
(iv) liaise with other groups
(v) develop the communications strategy
(vi) prepare technical and financial reports
(vii) raise funds
(viii) maintain frequent contact with the Steering Committee.

6.1.3. CCAFS Theme Leaders

The Theme Leaders will be appointed by the Steering Committee based on applications by interested people through an active search process. Ideally, Theme Leaders will collectively represent a balance of interests across CGIAR and ESSP. They will provide continuity of vision and intellectual leadership for their given Research Theme, and share responsibility for integrating Theme research into the overall CCAFS. In the initial phase, Theme Leaders will be appointed on a 50% time basis funded by CCAFS (with the flexibility to adjust this proportion as needs arise). The remaining 50% of their time will be funded by their host institution for them to continue their respective institution's activities and maintain a strong link to their science. Each will be assisted by a full time science officer funded by CCAFS (the amount of scientific assistance needed will be reviewed over time).

6.1.4. Advisory/Stakeholder Platform

The Platform will meet annually, and will be open to all interested parties to ensure a dialogue with all stakeholders and funding communities. Representatives from key agencies and stakeholder groups will be invited to share their visions for how CCAFS could develop in response to stakeholder needs. It will also offer a possibility for interaction with the funding community similar to the International Group of Funding Agencies for Global Change Research (IGFA). The Platform will:

(i) advise on the Program focus
(ii) propose mechanisms for communicating the Program results, and
(iii) provide a platform for dialogue with the donor community.

6.2. Host institution

The CCAFS Director and Secretariat will be hosted by an institution which is a member of either the ESSP constituency or the Alliance of the CGIAR Centers. The institution should demonstrate its ability to provide:

1. Financial, legal, human resources and office functions to the Program. This includes providing human resources services for staff of the Program, providing a legal entity through which the Program can establish all the contractual arrangements it needs, providing appropriate office space for the Program staff with associated IT support, providing financial management of the Program budget, under the oversight of the Program Director and Steering Committee.
2. A conducive scientific environment for the Program staff (i.e., it conducts climate change research of relevance to the objectives of the Program and is interested in collaborating in the Program).
3. Telecommunications with the rest of the world (telephone, internet, teleconferences) which are easy to use, totally reliable and cost-effective.
4. A geographical location, such that travel costs to the different sites where the work will be implemented and to the different partner institutions are kept to a minimum.
5. A cost-effective administrative support to the Program.
6. A suitable staff member to represent the institution on the Management Committee of the Program.

A cost-effective, non-bureaucratic, transparent host institution agreement to the Program, which covers all the above dimensions of hosting.

The institution will be located so as to maintain strong and frequent links with donors. There will be no involvement by institution senior management in CCAFS governance. This will distance the institution, helping to make clear that this arrangement would neither give the institution any advantage nor prejudice against it regarding engaging in CCAFS activities. Institutions will tender for the role of hosting the secretariat with the selection being made by the Chairs of the Alliance and the ESSP Science Committee in consultation with the CCAFS Chair. A Service Agreement will be developed to state clearly the host institution's responsibilities, detailing the tasks and the funding of the CCAFS secretariat.

6.3. Key appointments timetable

CCAFS **Chair:** The SC Chair was appointed by the Chair of the Alliance Executive and the Chair of the ESSP Scientific Committee in September 2008.

CCAFS **Steering Committee:** Based on nominations received from the Alliance and ESSP networks, the Chair of the Alliance Executive and the Chair of the ESSP Scientific Committee, in close consultation with the CCAFS Chair, invited initial SC members in December 2008. The first meeting of the SC CCAFS will take place in April 2009.

CCAFS **Director and host institution:** In November 2008, the post of Director of CCAFS was advertised and selection will be made in April 2009. The Alliance Centers and the ESSP constituency were also invited to express interest in hosting the CCAFS Secretariat. A final selection should also be made by April 2009. It is expected that the Director will be in place and a host institution agreement signed by June 2009 at the latest.

CCAFS **Theme Leaders:** A process for appointing these positions will be established by the CCAFS Steering Committee in consultation with the Director with a view to making appointments by mid-2009.

CCAFS **Regional Facilitators:** A process for appointing these positions will be established by the CCAFS Steering Committee at its first meeting.

6.4. Intellectual property (IP) asset management

CCAFS will generate a range of outputs intended in the main to be IPG. However, outputs may well arise warranting a formal IP agreement, especially if they are generated by partners who have a mandate to maximise the value of the IP owned by their institution. During the start-up phase a detailed CCAFS IP asset management plan will be developed by the CCAFS Secretariat working in close collaboration with the Steering Group, and in consultation with the CGIAR Central Advisory Service on Intellectual Property (CAS-IP). The agreed IP asset management plan will be appended to the host institution agreement.

6.5. Reporting mechanisms

- The CCAFS Chair and Director will give annual updates to the CGIAR Alliance and ESSP at their respective meetings. This will provide opportunity for formal, peer-review feedback at the highest level.
- The CCAFS Chair and Director will give annual updates to the Stakeholder Platform. This will ensure progress is maintained in line with stakeholder interests and needs, and that stakeholders are kept abreast of new initiatives as they are launched.
- The Chair will report annually to the CGIAR donors at the AGM (or at appropriate opportunities within the CGIAR Consortium as agreed to in principle during the 2008 AGM meeting in Maputo, December 2008); and to ESSP donors at the IGFA annual meetings. This will ensure CCAFS progress is maintained in line with donor interest; and donors are aware of emerging science issues.
- The Director will report annually to the host institution in line with employment terms, and twice a year to the Steering Committee. This will ensure work is conducted in a professional manner, and that satisfactory progress is made in terms of CCAFS delivery and collaborations.
- The Theme Leaders will report twice a year to the Steering Committee. This will ensure that Theme Leaders, both individually and collectively, are delivering agreed work plans and meeting key milestones. This will help ensure an integrated Challenge Program and that individual Themes do not deviate from the agreed work plan. It will also provide a check on the performance of individual Theme Leaders.

7. Budget and funding

7.1. Budget

CCAFS anticipates a ramped funding level from about US$10 million in the first year (2010) increasing to about US$25 million in year five. Phase 2 funding will be laid out in the detailed work plan to be delivered at a mid-term review. An indicative budget for Phase 1 is presented in Table 2.

7.2. Resource mobilisation strategy

Research, governance and management costs will be shared by a consortium of donors, including both 'traditional' CGIAR donors, ESSP donors and in-kind contributions from partners. A number of donors have already expressed their strong interest in supporting work under this CP. Initial funding for the period 2009 to 2010 will be available from the World Bank and the European Commission. Discussions for additional support have already been initiated with Danida, DFID and IDRC. These will be new funds rather than a redirection of funds currently allocated to other activities in the CGIAR system. The opportunities for collaboration between the respective donors of the international agriculture and the GEC research communities are very substantial, and these opportunities are currently being pursued. Examples of 'non-traditional' CGIAR donors include research councils, APN and IAI. The scenario activities are currently the subject of an ESSP-GECAFS proposal being discussed with the Bill and Melinda Gates Foundation and GEF, and collaboration would be to great mutual benefit. CCAFS's need for enhanced information management could form a proposal to the Google Foundation.

Table 2. CCAFS indicative budget for 2010-2014 (thousands USD).

COORDINATION	2010	2011	2012	2013	2014	Total for 5 Yrs	Average per Yr
Governance							
Chair + Steering Cmmtt	100	125	150	175	200		
Stakeholder Platform	100	125	150	175	200	1500	300
Management							
International Office (3, then 4 people)	450	500	600	600	600		
Travel and running costs	125	125	150	150	150	3450	690
Regional facilitation							
3 x Regional facilitator	300	300	350	350	350		
3 x Travel and running costs	150	175	200	200	200	2575	515
Coordination subtotal	1225	1350	1600	1650	1700	7525	1505
RESEARCH							
Themes							
6 x Theme Leaders 50% time	600	625	650	675	700		
6 x Theme Science Officer	600	625	650	675	700		
6 x Travel and running costs	300	350	400	400	400		
Generic research T1	750	1000	500	500	500		
Generic research T2	500	1000	1000	1500	1500		
Generic research T3	500	750	750	750	750		
Generic research T4	500	500	750	750	1000		
Generic research T5	500	500	750	750	1000		
Generic research T6	500	750	750	1000	1000		
Regional research T1	750	1500	1500	1000	1000		
Regional research T2	500	1000	1000	1000	1000		
Regional research T3	500	1000	1500	1500	2000		
Regional research T4	500	1500	2000	2500	3000		
Regional research T5	500	2000	3000	3000	4000		
Regional research T6	500	1500	2000	2500	3000		
CCAFS-wide							
Launch/Annual Conference	100	125	150	150	150		
3 x Scenario exercises	450	750	750				
Scenario Science Officer	150	150	175				
Scenario Science Officer Travel	50	50	50				
Integration and synthesis	500	500	750	750	1000		
S-N and S-S exchange visits	50	75	100	125	150		
Research subtotal	9300	16250	19175	19525	22850		
Grand Total (Coordination + Research)	**10525**	**17600**	**20775**	**21175**	**24550**	**94625**	**18925**
Total Theme research	**6500**	**13000**	**15500**	**16750**	**19750**	**71500**	**14300**
Theme 1 proportion of total Theme research	*23*	*19*	*13*	*9*	*8*		*14*
Theme 2 proportion of total Theme research	*15*	*15*	*13*	*15*	*13*		*14*
Theme 3 proportion of total Theme research	*15*	*13*	*15*	*13*	*14*		*14*
Theme 4 proportion of total Theme research	*15*	*15*	*18*	*19*	*20*		*18*
Theme 5 proportion of total Theme research	*15*	*19*	*24*	*22*	*25*		*21*
Theme 6 proportion of total Theme research	*15*	*17*	*18*	*21*	*20*		*18*
% of grand total on coordination	*12*	*8*	*8*	*8*	*7*		*8*

A %age cost on all pass-through funds will be negotiated with the Host Institution.

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Annexes

Annex 1. Leadership Group for coordination of the development of the Challenge Program on Climate Change, Agriculture and Food Security proposal and its Terms of Reference

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Richard Washington (University of Oxford/WCRP-CLIVAR)

Reiner Wassmann (IRRI)

It was coordinated by:

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Terms of reference for the Leadership Group were as follows:

1. Draft the full proposal taking into account the specific points raised by the CGIAR SC, meeting as required, but mainly working by email, etc.
2. Make decisions about INITIAL study regions based on IPCC and other reputable sources of information.
3. Co-opt appropriate national agricultural and GEC science partners for identified countries.
4. Review lessons learnt from reviews of other CPs on governance and management and propose a CP governance structure.
5. Disband upon submission of the proposal.

The Group built on earlier work that had developed a pre-proposal submitted to the CGIAR Science Council in September 2007.

Annex 2. Membership of the Steering Committee for the CGIAR Challenge Program on Climate Change, Agriculture and Food Security

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CLIMATE CHANGE
AGRICULTURE AND FOOD SECURITY

Alliance of the CGIAR Centers

Earth System Science Partnership

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