Assessments of Impacts and Adaptation to Climate Change

Final Report of the AIACC Project

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Report Prepared by: Neil Leary, Jyoti Kulkarni and Clark Seipt

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The International START Secretariat, 2000 Florida Avenue, NW, Washington, DC 20009, USA

AIACC Implementing Agency:

United Nations Environment Programme, Nairobi, Kenya

UNEP

Executing Agencies:

The International START Secretariat, Washington DC, USA
The Academy of Sciences for the Developing World, Trieste, Italy

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Professor Mohamed Hassan, Executive Director, TWAS
Professor Roland Fuchs, Director, START
Dr. Neil Leary, START Senior Scientist and AIACC Science Director

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The Report in Brief

The project Assessments of Impacts of and Adaptation to Climate Change in Multiple Regions and Sectors (AIACC) was implemented over the period 2001-2007. The project had three objectives: Enhance scientific capacity in developing countries to assess climate change impacts, vulnerability, and adaptation; Advance scientific understanding of these issues; and Improve links between climate change science and policy communities to enable adaptation planning and action.

Twenty-four assessments were executed in Africa, Asia, Latin America and Small Island States. Multi-institutional teams of more than 300 scientists, stakeholders and students from 50 developing countries conducted the assessments. The teams were supported by a capacity building program that included 'learning-by-doing', technical assistance, training workshops, regional science and policy workshops and engagement in international science and policy activities. Outcomes of the project include:

- More than 100 peer-reviewed publications, 2 books and more than 100 other publications that advanced knowledge;
- Participants taking leadership roles in international science activities;
- More than 100 citations of AIACC publications in the IPCC 4th Assessment Report;
- Outputs being used in National Communications;
- Working relationships established among scientific and stakeholder organizations;
- Enhanced capabilities of the 24 assessment teams; and
- Catalyzed south-south training activities.

> "The Fourth Assessment Report [of the IPCC] advances our understanding on various aspects of climate change based on new scientific evidence and research. A major contribution in this regard has come from the work promoted under the project Assessments of Impacts and Adaptation to Climate Change (AIACC)."
>
> "The record and outputs of the AIACC are impressive. . . The quality of the assessments is demonstrated by the more than 100 peer-reviewed publications produced, which benefited substantially the IPCC's Fourth Assessment Report. In view of this success, it is imperative that we build on the experience and achievements of AIACC and develop the next phase of such work to help advance new knowledge for a possible Fifth Assessment Report of the IPCC."
>
> R.K. Pachauri, Chairman, IPCC]

Selected findings from the assessments include:

- Climate variability, extremes and change are a danger now, not just in the distant future;
- The danger is greatest where natural systems are severely degraded and human systems are failing;
- Critical concerns include heightened water scarcity; increased flood risks; exacerbation of land degradation; threats to food security of rural poor; multiple pressures that converge in coastal zones; adverse health impacts where health care systems are weak; and ecosystem change and species loss;
- There is evidence of an adaptation deficit in all the AIACC study regions;
- Adaptation is needed now to close the deficits and is an essential first step towards adapting to climate change;
- Numerous obstacles impede adaptation and action is needed to enable adaptation processes;
- Recommendations for enabling adaptation include integrating adaptation with development; increasing awareness and knowledge; strengthening institutions; rehabilitating and protecting natural resources; providing financial assistance; involving those at risk; and using place-specific strategies.

The AIACC project was funded by the Global Environmental Facility, the Canadian International Development Agency, the United States Agency for International Development, the United States Environmental Protection Agency and the Rockefeller Foundation. The global change SysTem for Analysis, Research and Training (START) and the Academy of Sciences for the Developing World (TWAS) were the executing agencies for the project and the United Nations Environment Programme (UNEP) was the implementing agency. The project was sponsored by the Intergovernmental Panel on Climate Change (IPCC).

Summary of the Report

Introduction

The project Assessments of Impacts of and Adaptation to Climate Change in Multiple Regions and Sectors (AIACC) was conceived and implemented to address gaps in knowledge and scientific capacity in developing countries identified by the Intergovernmental Panel on Climate Change (IPCC) in its Third Assessment Report. The project had three objectives:

- Enhance scientific capacity in developing countries to assess climate change impacts, vulnerability, and adaptation;
- Advance scientific understanding of these issues; and
- Improve links between climate change science and policy communities to enable adaptation planning and action.

The AIACC project was funded by the Global Environmental Facility (GEF) as an enabling activity in the climate change focal area with a grant of US$7,5000,000. Financial support was also received from the Canadian International Development Agency (US$100,000), the United States Agency for International Development (US$300,000), the United States Environmental Protection Agency (US$50,000) and the Rockefeller Foundation (US$25,000). Participating developing country institutions provided in-kind co-funding valued at US$1,800,000.

AIACC Outcomes

Capacity building

24 assessment teams established
>300 participants from 50 developing countries gained experience in climate change assessment
>100 persons trained in AIACC training workshops
5 teams organized South-South training workshops
25 student theses supported and completed
Participants taking leadership roles in international science activities (e.g. IPCC, CCAA, ACCCA, START)
30 participants are authors of IPCC 4th Assessment Report
Successful new grant applications by many of the teams

Scientific knowledge

24 climate change assessments completed
>100 peer-reviewed publications
2 books published
>100 other publications
>100 citations of AIACC publications in IPCC AR4

Links between science and policy communities

Working relationships established by all 24 teams with stakeholder organizations
Scientific outputs being used in National Communications
Most teams engaged in National Communications activities
AIACC teams contributed to numerous national and international policy activities

The project was implemented over the period 2001-2007. Outcomes of the project are outlined in the box above and elaborated in the report. The global change SysTem for Analysis, Research and Training

(START) and the Academy of Sciences for the Developing World (TWAS) were the executing agencies for the AIACC project and the United Nations Environment Programme (UNEP) acted as the implementing agency. A project steering committee, chaired by the IPCC Chairman and composed of representatives of the GEF Secretariat and Scientific and Technical Advisory Panel; the UNFCCC Secretariat, Subsidiary Body on Implementation (SBI) and Subsidiary Body on Scientific and Technological Advice (SBSTA); the UN Development Program; and the World Bank, provided general oversight of project implementation. Scientific and technical advice for the execution of the project was provided by a project Technical Committee.

The primary activity of the AIACC project was the execution of twenty-four regional and national assessments of climate change impacts, vulnerabilities, and adaptation in Africa, Asia, Latin America, and islands of the Caribbean, Indian, and Pacific Oceans. Multi-institutional teams of developing country scientists, stakeholders and students conducted the assessments. The assessments were selected through merit review of submitted proposals and received endorsements from relevant GEF national focal points. Topics covered by the assessments include agriculture, forestry, fisheries, water resources, coastal systems, food security, rural livelihoods, human health and biodiversity (see Tables S-1 through S-4). More than 350 scientists, stakeholders and students from 150 institutions in 50 developing countries and 12 developed countries participated in the assessments. A list of institutions and countries is provided in Annex B of the full report.

The assessments were launched in 2002 and completed in 2005. The assessment teams were supported with grant funds and a comprehensive program of capacity building and networking that included 'learning-by-doing', technical assistance, training workshops, regional science and policy workshops, and engagement in international science and policy activities. The teams also participated in synthesis activities in 2006-2007 to compare results and derive common lessons. Through execution of the assessments and participation in project capacity building and networking activities, the participating institutions and individuals gained scientific and technical capacity, advanced scientific understanding and forged links between scientific institutions, key stakeholder organizations, and agencies responsible for policies related to climate change and the management of climate hazards.

This summary of the AIACC final report provides overviews of the findings from the assessments and project performance and presents recommendations for management of future assessments. The full report presents a synthesis of findings about climate change vulnerability (chapter 2) and adaptation (chapter 3), summaries of the objectives, approach and results of each of the 24 regional and national assessments (chapters 4 through 7), capacity building and networking outcomes (chapter 8), project outputs and their uses (chapter 9), a detailed assessment of project performance (chapter 10), and conclusions and recommendations (chapter 11).

The final report represents only one of the many outputs of the AIACC project. More than 200 papers, technical reports and student theses have been produced from the AIACC assessments, of which more than 100 have been published in peer-reviewed journals, books and the on-line *AIACC Working Papers*.[1] Many of these outputs are available online at www.aiaccproject.org.

Findings from AIACC

The AIACC project's 24 regional and national assessments investigated climate change vulnerabilities and adaptation response options in selected developing countries. The studies vary in their objectives, methods, systems, sectors, and locations. But most share an approach to the investigation of climate risks that emphasizes the integration of human and biophysical dimensions of vulnerability. Many also draw on the range of practices currently in use for managing present day climate risks to provide insights about adaptive capacity and potential strategies for adapting to future climate change.

[1] AIACC publications are listed in Annex A of the report.

While climate change vulnerability and adaptation are highly context-specific, a number of general lessons have been developed through comparison and synthesis across the AIACC studies. The general lessons are identified below and are elaborated in chapters 2 and 3 of the full report. More complete treatments of the context specific details and lessons from the individual assessments can be found in *Climate Change and Vulnerability* (Leary et al, 2008a) and *Climate Change and Adaptation* (Leary et al, 2008b).

Lessons about Climate Change Vulnerability

The propensity of people and systems to be harmed by stresses, referred to as vulnerability, is determined by their exposure to stresses, their sensitivity to the exposures, and their capacity to resist, cope with, exploit, recover from and adapt to the impacts. The AIACC regional assessments illustrate that vulnerability to adverse impacts from climate variation and change has multiple causes. The causes include climatic stresses as well as stresses that derive from interactions among environmental, demographic, social, economic, institutional, cultural, and technological processes. The state and dynamics of these processes differ from place to place and generate conditions of vulnerability that differ in character and degree. Consequently, populations that are exposed to similar climatic phenomena are not impacted the same. The most severe impacts that are of greatest concern generally are not expected to arise from climate stresses alone. Instead, such impacts are more likely when multiple stresses (climatic and non-climatic) interact to create conditions of high vulnerability. Some of the potential outcomes identified as high-level concerns and factors found to give rise to differences in vulnerability are described below.

Climate variability, extremes and change are a danger now, not just in the distant future. In each of the AIACC study areas, climate variations and extremes are immediate sources of risk. Climate hazards cause substantial damages such as loss of food and water supplies, reduced incomes, damaged homes and infrastructure, disruption of economic activity, degraded natural resources, disease outbreaks and loss of life. Global climate change is already occurring, has impacted natural and human systems, and now threatens to amplify the dangers (IPCC, 2007a and 2007b).

The danger is greatest where natural systems are severely degraded and human systems are failing. Natural resource systems that are severely degraded from overuse are highly sensitive to climate variations and have diminished resilience. Climate shocks can cause large and persistent losses of the goods and services from these degraded systems. Failing social, economic and governance systems typically cannot respond effectively to manage pressures on natural resources, cope with the impacts of climate and other shocks on their resource base, or adapt to the changing conditions. It is in contexts such as these, exemplified by AIACC case studies in Sudan (Osman-Elasha and Sanjak, 2008) and Nigeria (Nyong et al, 2008), in which the state of natural and human systems combine to create conditions of high vulnerability. Communities that are highly dependent on degraded resources and for which human systems are in or near a failed state are at greatest risk of worst-case outcomes such as collapse of rural livelihoods, deepening and widening poverty, displacement of population, hunger and famine, epidemics and violent conflict.

A corollary to this finding is that restoring and protecting natural systems and improving the performance of human systems can reduce vulnerability. The AIACC studies suggest that the potential severity and risk of many climate change outcomes are less where social, economic, and governance systems function in ways that enable effective responses to prevent, cope with, recover from and adapt to adverse impacts. Optimism ought to be tempered, however, by the reality of how challenging it has been to achieve even minimal progress where key human systems are dysfunctional.

Both heightened water scarcity and increased flood risks are critical concerns. Population and economic growth are increasing water demands and many parts of the world are expected to face water stresses that will constrain their development to an increasing degree. Climate change could either relieve or exacerbate water stress, depending on location and season, by increasing or decreasing water balances. While robust results for changes in annual and seasonal precipitation are emerging from climate models for some regions, for much of the world there continues to be high uncertainty about precipitation changes in the future. Given this uncertainty, results from AIACC studies are indicative of sensitivities and vulnerabilities to changes in water balances, but firm conclusions about likely outcomes require further study for most regions.

Climate change projections indicate the potential for drier future climates in AIACC study areas in southern Africa (Dube and Sekhwela, 2008; von Maltitz and Scholes, 2008), the Sudano-Sahel zone (Osman-Elasha and Sanjak, 2008; Nyong et al, 2008) and central Asia (Batima et al, 2008a; Yin et al, 2008a) that would negatively impact water supplies, ecosystems, biodiversity, food security, rural economies, human health and economic development. These impacts, if sufficiently severe, would retard progress toward Millennium Development goals. Vulnerability to adverse impacts from reduced water balances depends on many factors including the level and growth rate of water demand relative to reliable supply; water and land use policies; planning and management; water infrastructure; and the distribution and security of water rights.

In contrast, increases in average precipitation are suggested by many of the climate models for study sites in southeastern South America (Barros et al, 2008; Travasso et al, 2008), the lower Mekong River basin (Chinvanno et al, 2008a), the Philippines and Indonesia (Pulhin et al, 2008). For these areas, climate change may relieve water stress. But higher average rainfall, coupled with increases in intense rainfall events, also pose greater risks of flooding. Factors that exacerbate flood risks include growth in population and infrastructure in flood prone locations; exposure to coastal storm surge; poorly managed land use change; clearing of vegetation; filling of wetlands; and ineffective disaster prevention, preparedness, warning and response systems.

Land degradation may worsen in regions that become drier. Land degradation, an amplifier of vulnerability to climate change, is also a potential outcome of climate change. It is already a problem on intensively used marginal lands in AIACC study areas in arid parts of northwestern China (Yin et al, 2008a), Mongolia (Batima et al, 2008a), Mexico (Conde et al, 2008; Eakin et al, 2008; Wehbe et al, 2008), Botswana (Dube and Sekhwela, 2008), Nigeria (Nyong et al, 2008), South Africa (von Maltitz and Scholes, 2008) and Sudan (Osman-Elasha and Sanjak, 2008). Land use pressures from population growth and economic forces will build if current land use policies and incentives continue unchanged. If combined with a drier climate and increased frequency, severity and duration of droughts, the likelihood of more widespread and persistent land degradation would be high. Exacerbation of land degradation by climate change would harm human well-being and pose obstacles to development by decreasing land productivity, diminishing incomes, depleting resources for coping and adapting and eroding the resilience of the land and land-based livelihoods.

The livelihoods and food security of the rural poor are threatened by climate change. Rural economies, which are based on and dominated by agricultural, pastoral and forest production, are highly sensitive to climate variations and change. So too are the livelihoods and food security of those who participate directly in these activities, supply inputs to them, or use their outputs to produce other goods or services. The productivity of farm fields, pastures, and forests will be impacted by changes in water balances, temperatures, and climatic extremes, as well as by the beneficial effects of increased carbon dioxide concentrations. Although climate change can and will have both positive and negative impacts on rural economies and livelihoods, predominantly negative effects are expected in developing countries.

The AIACC studies demonstrate that systems with similar exposures to climate stimuli can vary considerably in their vulnerability to damage from the exposures. Factors both internal and external to the household determine its vulnerability to climate change. External factors found to increase the vulnerability of rural households include a high proportion of households engaged in subsistence or small scale farming or herding on marginal lands; scarcity of water and other resources; rapidly growing population; poorly diversified income opportunities in the local economy; high poverty rates; inadequate health, education and other services; lack of social safety nets; gender inequality; declining local authority; governance failures; violent conflict; and competition from market liberalization (Adejuwon, 2008; Batima et al, 2008a; Chinvanno et al, 2008a; Eakin et al, 2008; Dube and Sekhwela, 2008; Nyong et al, 2008;Osman-Elasha and Sanjak, 2008; Ziervogel et al, 2008). Internal factors are addressed by the next lesson.

A household's access to water, land, and other resources is an important determinant of its vulnerability. The sensitivity of a household's livelihood and food security to changes in climate and land productivity and its capacity to respond are shaped to a significant degree by the resources available to it. Findings from case studies of rural communities in southern Africa, the Sudano-Sahel zone, South America and Southeast and Central Asia reveal that internal characteristics of households that are determinants of their vulnerability include access to safe water and sanitation; security of water rights; land-tenure status; farm size and soil quality; number of animals owned; quantity and quality of household labor supply; ownership of farm equipment; amount and diversity of household income; financial savings; access to credit; food stores; health status of household members; and gender of household head (Batima et al, 2008a; Chinvanno et al, 2008a; Eakin et al, 2008; Nyong et al, 2008;Osman-Elasha and Sanjak, 2008; Pulhin et al. 2008; Ziervogel et al, 2008).

Multiple factors converge to make the people inhabiting coastal zones and small islands highly vulnerable. Coasts and small islands are highly exposed to a variety of climate hazards that may be affected by global climate change. The climatic hazards converge with local and regional human pressures to create conditions of high vulnerability, particularly in areas with high concentrations of people and infrastructure along low-lying coasts. Climate factors that influence the vulnerabilities of coasts and small islands include sea-level rise; the frequency and intensity of tropical and extra-tropical storms; changes in winds, water temperatures, and freshwater inflow to estuaries and coastal waters; ENSO and monsoon variability; and water balances. Non-climate drivers include land use planning and management; flood and erosion control; health of wetlands, reefs, and other natural barriers; systems for disaster prevention, preparedness, warning, and response; dependency on tourism; and pollution.

Along the Argentine coast of the Rio de la Plata, projected changes in sea level are expected to increase the area and population affected by recurrent flooding from storm surges – hundreds of thousands of additional people are estimated to be at risk during the 21st century (Barros et al, 2008). Acceleration of coastal erosion due to climate change is a concern in Fiji and the Cook Islands (Mataki et al, 2005). In the Seychelles, coral bleaching has reduced the ability of reefs to dissipate wave energy, accelerating beach erosion, reef degradation, and damage to coastal infrastructure (Sheppard et al, 2005). The islands' strong dependency on tourism and the high sensitivity of their tourism attributes (e.g., beaches, hotels) to climate hazards creates conditions of high socioeconomic vulnerability to climate change (Payet, 2008).

Vulnerability to adverse health impacts is greater where health care systems are weak and programs for disease surveillance and prevention are lacking. Many vector-borne infectious diseases are climate sensitive and epidemics of these diseases can occur when their natural ecology is disturbed by environmental changes. Projected changes in rainfall and temperature have the potential to expose more people to vector-borne diseases, such as malaria in the highlands of East Africa and dengue fever in the Caribbean, by expanding the geographic range of vectors and pathogens into new areas, increasing the area of suitable habitat and the numbers of disease vectors in endemic areas, and extending the length of transmission seasons (Heslop-Thomas et al, 2008; Wandiga et al, 2008). Changes in the incidence, extent, and severity of disease epidemics depend on more than climate stresses and disease ecology, however. Demographic, social, economic and other factors also determine exposure, transmission, infection, treatment, and prognosis. Vulnerability to severe health outcomes is greatest where health care systems are degraded; where large numbers of people lack access to health care; where a population's immunity, nutrition, and general health status is low; and where effective programs for disease surveillance, vector control, and prevention are lacking. Where the converse of these conditions holds, the likelihood of severe health outcomes is much diminished.

Some ecosystems and many of their species may be lost to climate change. Climate change is already having observable impacts on ecosystems and by the end of the 21st century may become the dominant driver of ecosystem change and biodiversity loss. The vulnerability of ecosystems and species to climate change is influenced by the specificity of their climate requirements, the change in spatial extent of areas that match those requirements, the degree of connectivity between suitable areas, the rates at which suitable climates move across the landscape, and the rates at which different species can migrate. Vulnerability is also shaped by other human-caused pressures that weaken ecosystem resilience and by land uses that fragment the landscape and pose barriers to species migration.

An AIACC study of ecosystem responses to climate change in South Africa finds that the Succulent Karoo biome, an arid ecosystem rich in biodiversity and high in species endemism, could disappear almost entirely, resulting in extinction of many of the species endemic to the biome (von Maltitz and Scholes, 2008). Also vulnerable, but likely less so, is the fynbos biome, which is the major vegetation type of the highly diverse Cape Floral Kingdom. Many fynbos species are projected to be able to migrate with climate driven shifts in their habitats, but some will not and will be lost. The savannas are found to be the least vulnerable of the South African biomes studied. In the Philippines, increasing temperature and rainfall are projected to cause dry and moist forest types to disappear and be replaced by wet forests and rainforests (Lasco et al, 2008). The transition would likely result in the loss of many dry and moist forest species.

Lessons about Climate Change Adaptation

Adaptation to climate is not new. People, property, economic activities and environmental resources have always been at risk from climate hazards and people have continually sought ways of adapting. Broadly speaking, we are adapted to cope with a wide range of climatic conditions and stresses. But variations and extremes do regularly exceed coping ranges, too often with devastating effect. While climate impacts can never be reduced to zero, the heavy and rising toll of weather-related disasters and the burden of less severe variations indicate that we are not as well adapted as we might or should be. There is, at present, an adaptation deficit (Burton, 2004).

All the AIACC case studies find evidence of an adaptation deficit in their study areas. But they also find and document a variety of adaptive practices in use that have reduced vulnerability to climate hazards. In most cases these have been adopted in response to multiple sources of risk and only rarely to climate risk alone. General strategies in use in the study areas include increasing the capacity to bear losses by accumulating food surpluses, livestock, financial savings and other assets; hedging risks by diversifying crops, income sources, food sources and locations of production activities; reducing exposures to climate hazards by relocating, either temporarily or permanently; spreading risks through kinship networks, pooled community funds, insurance and disaster relief; reducing the sensitivity of production and incomes derived from natural resources by restoring degraded lands, using drought resistant seed varieties, harvesting rainfall, adopting irrigation and using seasonal forecasts to optimize farm management; preventing climate impacts through flood control, building standards and early warning systems; and increasing the capacity to adapt through public sector assistance such as extension services, education, community development projects, and credit services.

These and other strategies in use are evidence that the vulnerable can and do act to reduce their vulnerability to climate hazards. They also provide a rich base of experience on which to build for adapting to future climate change. But climate change is altering exposures to climate hazards. The frequency, variability, seasonal patterns, spatial distribution and other characteristics of climate events and phenomena are changing. The changes will push future climate variations and extremes outside the bounds of what people have been exposed to and had to cope with in the past. An implication is that current practices, processes, systems and infrastructure that are more or less adapted to the present climate will become increasingly inappropriate and maladapted as the climate changes. That is, the adaptation deficit is likely to grow. Fine-tuning current strategies to reduce risks from historically observed climate hazards would not be sufficient in this dynamically changing environment. More fundamental adjustments will be needed. This will require recognizing what changes are happening, anticipating the range of likely future changes, understanding the vulnerabilities and potential impacts, identifying appropriate adjustments, and mobilizing the resources and will to implement them.

Following are lessons from the AIACC studies that can help to guide a transition from coping with current climate hazards to adapting to future climate change. They are formulated as recommendations for action.

Adapt now! The current deficit in adaptation makes it imperative to adapt now. Doing so would have immediate benefits in reduced weather-related impacts and increased human welfare. The need to adapt is made more urgent by climate change, which is now upon us and is widening the deficit. Numerous practices currently in use, some identified by the AIACC studies, but many others as well, can be expanded and replicated to reduce climate risks. Adapting to better manage current climate risks is an essential step towards adapting to future climates.

Create conditions to enable adaptation. Vulnerable people have a strong self-interest in adapting. But numerous obstacles impede adaptation, constraining what people can and are observed to do. Common impediments include competing priorities; poverty; lack of awareness, information and knowledge; uncertainty; weak institutions; degraded natural resources; eroded social capital; inadequate infrastructure; insufficient financial resources; distorted incentives; and poor governance. Interventions are needed to create conditions that enable people to surmount the obstacles and take actions to help themselves. Indeed, enabling the *process* of adaptation is the most important adaptation that the public sector can make. Interventions to enable adaptation are exemplified in the lessons and examples that follow.

Integrate adaptation with development. The goals of climate change adaptation and development are strongly complementary. The impacts of current climate hazards and projected climate change threaten to undermine development achievements and stall progress toward important goals. Adaptation can reduce these threats. In turn, development, if appropriately implemented, can help to enable climate change adaptation. Integrating adaptation with development planning and actions can exploit the complementarities to advance both adaptation and development goals. To be effective, integration needs to engage ministries that are responsible for development, finance, economic sectors, land and water management, and provision of public health and other services. It is in agencies such as these that key decisions are taken about the allocation of financial and other resources. And it is within these agencies and among their stakeholders where much of the sector-specific expertise resides that must be engaged.

Increase awareness and knowledge. Nearly all of the case studies highlighted lack of knowledge as a critical constraint on adaptation and rank efforts to increase and communicate knowledge as a high priority. Stakeholders complain of limited to no access to information about historical climate and future climate change projections; estimates of climate impacts and risks; causes of vulnerability; and risk management technologies and practices. The AIACC study in Tunisia, for example, indicates that local farmers are reluctant to modify traditional agricultural practices because they lack the knowledge and education to evaluate and implement new methods (Mougou et al, 2008). Similarly, smallholder farmers in Tamaulipas, Mexico, lack the know-how for adopting potentially beneficial irrigation strategies (Wehbe et al, 2008). Artisanal fishers of the La Plata estuary need information about the effects of climate variations on fish stock movement and fish catch, forecasts of fishing conditions, and methods and technologies for managing climate variability (Nagy et al, 2008). Herders in Mongolia voiced a strong need for education and training in methods for improving the resilience of their pastures and livestock with respect to climate extremes (Batima et al, 2008b). Evidence of information problems within the AIACC case studies demonstrates the need for programs that help advance, communicate, distribute, interpret, and apply knowledge for managing climate risks.

Strengthen institutions. Institutions are found to play important roles for enabling adaptation. Local institutions, including community organizations, farmer associations, local government agencies, informal associations, kinship networks and traditional institutions, serve functions in communities that help to limit, hedge and spread risks. They do this by sharing knowledge, human and animal labor, equipment and food reserves; mobilizing local resources for community projects and public works; regulating use of land and water; and providing education, marketing, credit, insurance and other services. Provincial, national and international institutions aid by providing extension services, training, improved technologies, public health services, infrastructure to store and distribute water, credit, insurance, financial assistance, disaster relief, scientific information, market forecasts, weather forecasts and other goods and services.

In many of the AIACC case studies, key functions of risk management are inadequate or absent due to weaknesses in supporting institutions. The institutions are often poorly resourced, lacking in human capacity, overloaded with multiple responsibilities, and overwhelmed by the demands of their communities. In some instances, traditional institutions have been diminished in role by socioeconomic changes and government policies. For example, in Botswana's Limpopo Basin, traditional institutions such as the *Kgotla*, a forum for local decision-making and justice, family-based land rights and the *mafisa* system of cattle lending historically played important roles in limiting the local community's vulnerability to climate and other hazards (Dube and Sekhwela, 2008). But these institutions were weakened during the 20th century. As a result, the capacity to adapt decreased and vulnerability increased as community members were alienated from decisions about their local resources, poverty deepened, and dependence on government interventions increased. Strengthening institutions to fill strategic functions in support of adaptation is needed in many vulnerable communities.

Protect natural resources. A high proportion of livelihoods, economic activities, and national incomes in developing countries are dependent on climate-sensitive natural resources. Too often, the resources are degraded by the pressures of human use and climatic and environmental variations and change. As noted in the previous section, their degraded state makes the resources, and the people who are dependent on them, highly vulnerable to future damages from climate change.

Rehabilitating and protecting natural resources is a focus of adaptation strategies in contexts as varied as crop farming and livestock systems in the African Sahel (Dabi et al, 2008; Osman-Elasha et al, 2008), the South American Pampas (Wehbe et al, 2008), central Asia (Batima et al, 2008b; Yin et al, 2008b) and the lower Mekong basin (Chinvanno et al, 2008b); malaria control in the East African highlands (Yanda et al, 2008); biodiversity conservation in southern Africa (von Maltitz et al, 2008); fisheries in the Rio de la Plata (Nagy et al, 2008); watershed management in the Philippines (Lasco et al, 2008b); tourism in the Seychelles (Payet, 2008); and coastal townships in Fiji (Mataki et al, 2008). Progress in many of these contexts will require changes in incentives; reforms of tenure to land, water, and natural products; education; training; and more vigorous enforcement of regulations. These, in turn, are dependent on strong institutions and access to financial resources.

Provide financial assistance. Stakeholders in the AIACC study areas commonly cite lack of financial resources as a major obstacle to adaptation. The constraint is particularly binding on the poor and very poor, who are typically among the most vulnerable to climate change. Poor households, small-holder farmers and small business owners often lack access to formal credit markets and insurance. They resort to community funds and informal networks for credit to recover from losses or make investments that reduce risks. Private sector innovations in micro-credit and micro-insurance have increased access to financial resources and could play a role in financing adaptation. Some national governments assist with direct financial payments and with subsidized credit and insurance, but the assistance directed toward the rural and urban poor is diminishing in many places (Eakin et al, 2008). At the international level, financial assistance is provided through the Global Environmental Facility and international aid agencies. International funding is acting as a catalyst for raising adaptation awareness, building capacity, improving understanding of risks and response options, engaging governments in prioritizing and assessing options and, to a limited extent, implementing selected adaptation measures. Nevertheless, the financial needs of adaptation are far greater than current funding. Additional financial resources are necessary. Ultimately, adaptation financing must come from multiple sources, including those internal to developing countries.

Involve those at risk. Involving persons at risk in the process of adaptation, the intended beneficiaries, can increase the effectiveness of adaptation to climate change. Many of the AIACC case studies involved at-risk groups in assessment activities. In the Argentina-Mexico study, the participation of at-risk farmers and water managers provided guidance on risk perceptions and information needs that contributed to brochures for public education and led to development of practical options for water and agricultural practices and policy. The AIACC study in Zimbabwe, Malawi, and Zambia employed a focus group approach that brought together analysts, stakeholders, and local and national policymakers to examine impacts of prolonged drought and coping strategies. The focus groups identified a number of intervention strategies that meet local needs. In Sudan, a variety of participatory methods were used to engage community members and learn their perspectives about the effectiveness of past development projects for improving livelihoods and reducing vulnerability to drought. The participatory activities in Sudan identified financial capacity, access to low-tech tools and materials and development and improvement of local infrastructure as key factors for building resilience to climate variation and change. In Mongolia, herders, authorities from local and national offices and scientific experts participated in workshops to develop criteria for evaluating adaptation options and to rank options by applying the criteria. Measures that generate near-term benefits by improving capacity for reducing the impacts of drought and harsh winters, as well as measures that produce long-term benefits by restoring and improving pastures, emerged as priorities.

These and other experiences demonstrate the potential of participatory approaches for focusing attention on risks that are priorities to the vulnerable, learning from risk management practices currently in use, identifying opportunities and obstacles, applying evaluation criteria that are relevant and credible to at-risk groups, drawing on local knowledge and expertise for identifying appropriate strategies, and gaining local ownership for proposed options. A common result of involving those at risk is that it forces climate risks to be examined in context with other problems that are priorities for the community and gives emphasis to solutions that can be combined to attain multiple objectives. This can help mobilize local support and resources that are necessary for successful adaptation.

Use place-specific strategies. Adaptation is place-based and requires place-specific strategies. Although the climate change adaptation lessons discussed in these pages are useful, they oversimplify the rich, detailed stories of the AIACC case studies. This ninth lesson thus confirms that many more adaptation lessons were learned from the AIACC studies, many of which are specific to the particular contexts of particular places. For instance, two AIACC case studies – one based in Jamaica (Taylor et al, 2008), the other in the highlands of Lake Victoria (Yanda et al, 2008) – investigate health risks from climate-influenced, mosquito-borne diseases. In each context, however, responses to the diseases differ as a function of differences in public health infrastructure and access to health care. While general lessons can be applied across different settings to help guide adaptation strategies, the characteristics of the local context will always determine the specific approaches and practices that will function most effectively.

Capacity Building and Networking

Capacity building was a primary emphasis of the AIACC project. While each of the assessments was executed by a very capable team that possessed strong scientific expertise in the disciplines relevant to the systems investigated, the teams had varying degrees of experience and familiarity with the assessment of climate change impacts, vulnerability, and adaptation. Few had extensive experience with multidisciplinary research or assessment that encompassed physical, biological, and social sciences. For many of the participants, the AIACC case studies marked their first direct participation in a multi-sector, multidisciplinary project.

The AIACC project used an innovative approach that integrated learning-by-doing, technical assistance, training, and networking activities. Each of these components is described below. This comprehensive package of capacity building activities yielded near- and long-term benefits. In the near-term, the activities helped to assure the success of the 24 AIACC regional assessments. For the longer-term, the activities enhanced capacity for (i) more comprehensive and more advanced future assessments that will add to the scientific knowledge base, (ii) science-stakeholder linkages to develop and apply the knowledge base to support adaptation, (iii) contributions to national communications and adaptation planning, (iv) contributions to international science activities such as the global assessments of the IPCC, and (v) participation in international environmental policy processes such as negotiations under the UNFCCC.

Learning-By-Doing

More than 350 scientists, stakeholders and students actively participated in the AIACC regional and national assessments. By collaborating with others with diverse backgrounds and areas of expertise, the participants learned essential skills for integrated assessment. Learning by doing, the scientists developed skills for coordinating work by different disciplinary experts, recognizing and accounting for cross-system interactions and feedbacks, integrating results across multiple sectors and scales, and synthesizing findings in ways that are useful for adaptation planning by stakeholders. The most important capacity building occurred in the opportunities to work in multi-disciplinary, multi-institutional, and multi-country teams to undertake highly integrated assessments of coupled biophysical and human systems.

Technical Assistance

A technical advisor was assigned to each regional study team as a project resource. The advisors were available to provide guidance on project design, objectives, implementation, methods and tools. The advisors assisted with data access, construction of regionalized climate change scenarios and the application of different methods and tools to assess vulnerability to climate change, evaluate adaptation options, and to engage stakeholders. They reviewed and provided feedback to project teams on papers, reports and other outputs of their assessments. The AIACC technical advisors were drawn from the IPCC and included experts from developing and developed countries.

Training

Training activities were carried out on multiple, reinforcing levels. These include global training workshops organized by the executing agencies, training activities organized and executed by the assessment teams themselves, and south-south training activities in which assessment teams provided training to other teams in the AIACC network.

During the first year of the project, three global training workshops were hosted for participants from all 24 of the regional assessments. The first, a project kick-off workshop held at UNEP Headquarters in Nairobi, Kenya, provided an introduction and broad overview of climate change assessment methods and was an opportunity for the teams to learn from one another and refine their project work plans. The second global workshop was co-organized and hosted by the Tyndall Centre for Climate Change Research at the University of East Anglia. It provided training on methods and tools for the design and application of climate scenarios in the regional assessments. The third global training workshop, organized in collaboration with the Stockholm Environment Institute – Oxford and hosted by TWAS in Trieste, Italy, focused on methods for vulnerability and adaptation assessment.

A supplemental grant program provided resources to the assessment teams for capacity building needs not met by the global workshops and also for stakeholder engagement activities. The program awarded small grants to the teams that were used for further training and capacity building in climate modeling and scenario construction, water balance modeling, watershed management, crop system modeling, and GIS tools and methods. Small grants were also used for a variety of stakeholder and policy workshops.

Several AIACC assessment teams implemented south-south training activities with and for other teams in the AIACC network. For example, the climate analysis group at the University of Cape Town held a workshop on regional climate modeling for researchers from other AIACC projects in Africa. The workshop was organized in collaboration with the Hadley Centre and with AIACC support. CPTEC-INPE and the Hadley Centre conducted a similar workshop in Brazil in which several of the AIACC projects in Latin America participated. The assessment team for the lower Mekong basin project provided training in hydrologic modeling at Chulalongkorn University to members of an AIACC assessment in the Philippines. In turn, the Philippines project conducted training workshops for scientists in Vietnam, Lao PDR, and Cambodia and used a portion of its grant to help its neighboring scientists implement mini-assessments of their own. An AIACC assessment led by CSIR in South Africa implemented a training course on biodiversity conservation in a changing climate for resource and wildlife managers from across Africa. The course is now being offered via the internet by the University of the Western Cape. These examples of south-south transfers of capacity are a very encouraging sign that the capacity being established through AIACC is not only sustainable – it is also extending beyond the project's direct participants.

Networking

The AIACC project established networks that link scientists across disciplines, institutions across institutional boundaries, countries across borders, and scientists with stakeholders. The networks established and nurtured by AIACC are a critically important form of capacity needed to comprehensively understand climate change vulnerabilities, evaluate adaptation strategies, and share knowledge and perspectives across stakeholder groups. Scientists from different disciplines and institutions have built a foundation for future scientific collaboration on climate change. Scientists and stakeholders from various parts of civil society are collaborating to consider the risks of climate change and how to adapt to those risks. Multi-country AIACC projects have also resulted in significant inter-country collaborations in Eastern, Southern and Northern Africa; Southeast Asia; and South America.

Six regional workshops were organized by the AIACC project, two each in Africa, Asia-Pacific, and Latin America-Caribbean. The workshops brought together AIACC investigators and members of the science and policy communities of the different regions to learn from one another about ongoing research and assessment, methodological issues, regional concerns, informational needs, and capacity building needs. At the second workshop in each region, stakeholders associated with each of the regional/national assessments were invited to participate. The workshop interactions led to a number of cross-project initiatives to share expertise, including the south-south training activities described in the previous section.

Important connections with international organizations have been enhanced by the AIACC project. The IPCC requested AIACC's advice to identify developing country scientists to involve in the planning of the 4^{th} Assessment Report (AR4) and subsequently to be authors of the report. As a result of these consultations, a dozen AIACC participants were engaged in planning the AR4 and more than 30 are authors of report. Involvement with the IPCC has helped the scientists to develop professional relationships with leading researchers from around the world. AIACC scientists have also been invited to be authors for the Millennium Ecosystem Assessment (MEA) and the International Assessment of Agricultural Science and Technology (IAAST). AIACC has organized sessions and facilitated presentations by project scientists at numerous international conferences, including those of the International Human Dimensions Programme, the Earth System Science Partnership, UNEP, the Stanford Energy Modeling Forum, the UK Met Office, the Chinese Academy of Sciences, expert meetings of SBSTA and IPCC, and side events at UNFCCC Conferences of the Parties (COP). In addition, many AIACC participants are now active in the START and TWAS networks.

Project Outputs and their Use

Major outputs of the AIACC project can be grouped into three categories: regional climate change assessments, human and institutional capacity, and scientific knowledge.

Regional Climate Change Assessments

Twenty-four climate change assessments were completed under the AIACC project. Technical reports from each of the assessments are available at www.aiacproject.org. The assessments are currently being used to:

- Provide a stronger scientific basis for the vulnerability and adaptation assessments of countries' National Communications to the UNFCCC;
- Inform national delegations to the UNFCCC COPs about key issues;
- Raise the awareness of stakeholders and the general public about climate change vulnerability and adaptation;
- Advance scientific understanding and inform the 4^{th} Assessment Report of the IPCC on these issues as they pertain to developing countries; and
- Inform the consideration and development of adaptation strategies at local and national scales.

All 24 AIACC teams established contacts and shared scientific outputs with entities responsible for National Communications and National Adaptation Programs of Action (NAPA). Many of the teams have been asked to formally contribute to National Communications and NAPAs and several are in key leadership roles for planning and preparing their countries' 2^{nd} National Communications. Interactions between AIACC teams and stakeholder groups are continuing and contributing to adaptation planning. Selected examples of how AIACC outputs are contributing to National Communications, NAPAs and other activities are described in Chapter 9 of this report. Additional examples can be found in the summaries of the regional assessments (presented in Chapters 4-7) and in their technical reports.

Human and institutional capacity

A second important output of the AIACC project is enhanced capacity that enables scientists, technical experts, and scientific institutions of developing countries to:

- Undertake comprehensive, advanced climate change assessments and add to the climate change knowledge base;
- Link science and stakeholder communities to develop and apply this knowledge to support adaptation;

- Contribute to national communications and adaptation planning;
- Contribute to international science activities such as the IPCC assessments;
- Participate in international and national environmental policy processes; and
- Transfer capacity to others.

Evidence of the enhanced capacity and its uses are multiple. The substantial output of peer-reviewed scientific publications, described in the next section, demonstrates the high scientific capacity of the project participants for research and assessment that have expanded the knowledge base. Almost all of the teams established working relationships with stakeholder groups that have yielded common understanding of climate change vulnerabilities and adaptation options. These working relationships, documented in the final reports of the regional assessments, represent important capacity for continued application of scientific knowledge to support adaptation and National Communications. The participation of 30 AIACC scientists as authors of the IPCC AR4 and other activities amply demonstrate the use of AIACC capacity in international science activities. The various south-south training activities that were spawned by AIACC give evidence that capacity developed by the project is being transferred to others.

AIACC capacity contributed to the development of the NAPA guidelines and has also been applied in NAPA preparations in Sudan, Malawi, Mozambique, Zambia and the Gambia. Several AIACC investigators, drawing on their AIACC experiences, co-authored technical papers for UNDP's Adaptation Policy Framework. AIACC investigators have used capacity developed in the project to contribute to and present at policy conferences such as Adaptation and Development Days held annually at UNFCCC COPs; the UNEP/SEI/IIED Adaptation Research Workshop in New Delhi, 2004; the Adaptation Science and Policy Conference in Beijing, 2004; expert workshops of SBSTA; and numerous national policy dialogues (e.g. Mongolia, Mexico, Argentina and South Africa). A presentation was made to SBSTA in May 2007 on how the achievements of AIACC can help advance the goals of the Nairobi Work Programme (NWP) and action pledges have been made to draw on the experiences of AIACC to support the NWP.

Several of the teams have succeeded in new grant applications from Climate Change Adaptation in Africa (CCAA), Advancing Capacity to Support Climate Change Adaptation (ACCCA) and others, demonstrating that they have gained important capacity and are applying it to the problems of climate change research and adaptation. A number of the participants are taking up leadership roles in the global change science community, including membership on the science committee of the CCAA program, the project management team for the ACCCA project, the IPCC Task Group on Data Scenario Support for Impact and Climate Analysis, the Pan-African Committee of START, and the steering committee for AFRICANESS.

Scientific knowledge

Substantial in number, the scientific publications from AIACC exceed what is achieved by comparable projects. The publications help to fill important gaps in the scientific literature on climate change vulnerability and adaptation in developing countries that were identified by the IPCC Third Assessment Report. As of the writing of this report, more than 200 papers, reports, books and student theses have been produced by the AIACC project. More than 100 of these are peer-reviewed, including over 60 papers published in peer-reviewed journals and books and more than 40 in the peer-reviewed *AIACC Working Papers* series (available online; see www.aiaccproject.org). Journals in which AIACC papers have been published include *Ambio, Climate Research, Conservation Biology, Geophysical Research Letters, Global Environmental Change, International Journal of Climatology, Journal of Climate, Journal of Environment and Development, Journal of Geophysical Research, Mitigation and Adaptation Strategies for Global Change* and *Theoretical and Applied Climatology*. A list of publications can be found in Annex A of the full report. The number of peer-reviewed publications, and the more than 100 citations to AIACC publications in the new IPCC AR4, is evidence of the high quality and impact of the scientific output of the project.

Chairman of the IPCC, Dr. R.K. Pachauri, gives the following assessment of the impact of the AIACC project on the IPCC assessment: "The Fourth Assessment Report advances our understanding on various aspects of climate change based on new scientific evidence and research. A major contribution in this regard has come from the work promoted under the project Assessments of Impacts and Adaptation to

Climate Change (AIACC). . . The record and outputs of the AIACC are impressive. . . The quality of the assessments is demonstrated by the more than 100 peer-reviewed publications produced, which benefited substantially the IPCC's Fourth Assessment Report. In view of this success, it is imperative that we build on the experience and achievements of AIACC and develop the next phase of such work to help advance new knowledge for a possible Fifth Assessment Report of the IPCC."[2]

Conclusions and Recommendations

Conclusions about scientific findings of the AIACC project were summarized in Section 2. This closing section presents conclusions and recommendations about project implementation.

Achievements and remaining gaps. The AIACC project made important progress on the objectives of advancing knowledge, enhancing scientific capacity and improving links between science, policy and stakeholder communities, as documented in this report. However, substantial gaps remain. Some of the important gaps in knowledge include:

- Characterization of the range of future exposures to climate hazards at regional and finer spatial scales that are important for adaptation decisions;
- Identification and prioritization of climate hazards that are of highest concern for different sectors, systems, places and groups and investigation of how these hazards will change with human-caused climate change;
- Measurement of vulnerability of different groups, empirical validation of the measurements, and attribution of differences in vulnerability to proximate and underlying causes;
- Decision processes of different classes of actors for managing climate risks, the information needed to make good decisions, and how climate change information can be integrated into decision making processes;
- The role of institutions (rules, processes and organizations) in facilitating or limiting adaptation to climate hazards;
- Identification of effective strategies for enabling adaptation and lessons about how strategies that are successful in one context can be expanded in use or transferred to other contexts; and
- The benefits and costs of adaptation.

It is not unexpected that gaps remain. After all, despite global change research budgets of several billion dollars per year in the developed countries, there remain important gaps in knowledge, capacity and linkages in those countries as well. Making progress on filling these gaps is critically important for managing and reducing climate risks in the developing countries, and most particularly in the least developed countries. The AIACC project has demonstrated that a well designed project of relatively modest scale that invests in developing country science can yield substantial benefits. More projects of this type are needed. The remaining conclusions address lessons from AIACC for the design of effective projects for advancing knowledge, building scientific capacity and linking science, policy and stakeholder institutions.

Peer-review and scientific quality. The AIACC regional and national assessments were selected through peer-review of the scientific merit of proposals submitted in response to an open call. This process resulted in the selection of a very high quality set of climate change assessments and was an important contributor to scientific success and productivity of the project. However, it was also recognized that a purely scientific-merit approach to selecting projects would exclude institutions and countries in greatest need of scientific capacity development. To mitigate this outcome, weight was given in the review process to proposals from countries with low capacity that were basically sound in their objectives and general approach, that included appropriate types of institutions and participants, but for which the then existing capabilities of the proposal team were potentially lacking in some areas. A number of such proposals were selected and their successful execution was supported by the various capacity building activities of the AIACC project. The performance of these projects demonstrated that the selections were wise, that the

[2] From the foreward to *Climate Change and Vulnerability*, Leary et al, 2007a.

approach to capacity building was effective, and that the approach can be used as a model for engaging institutions from the least developed countries in climate change assessment.

Flexible, bottom-up management. Management of the project devolved considerable responsibility to the developing country teams that executed the assessments. Objectives, methods, tools and scenarios were not dictated to the teams by the project; nor were the sectors and systems to be investigated. The Technical Committee, composed of highly capable and dedicated individuals with internationally recognized expertise, provided guidance to the assessment teams as well as to the AIACC management team. But the teams were given wide latitude to set their specific objectives, focus on sectors and issues of their choosing and select the methods and tools to be applied. This allowed for a high degree of innovation and matching of the focus and design of each assessment to the priorities, capabilities and interests of the teams. During the execution of the assessments, in response to stakeholder feedback, many of the teams recognized that their assessments gave insufficient attention to use of their scientific findings by stakeholders and policy makers. Management of the project adapted to the shifting priorities by allowing and supporting the assessment teams to revise their work plans and budgets and also by leveraging new funding to expand stakeholder activities. The flexible and 'bottom-up' approach to project management created good working relationships and respect among the participating institutions and was a key factor in the overall performance of the project.

Coordination of multiple assessments. Execution of multiple climate change assessments under the umbrella of a larger project produced substantial synergistic benefits. The AIACC project provided numerous opportunities for the different assessment teams to interact with each other through regional workshops, synthesis activities, joint training activities, peer-review of each others work, and electronic communications. As noted below, these interactions made important contributions to capacity building. Executing a group of assessments together also made it possible for investigators from multiple projects of broadly similar design to compare results from across the projects and to identify and synthesize common lessons.

Multiple, reinforcing activities for capacity building. A comprehensive program of learning-by-doing, technical assistance, group training, self-designed training and networking was demonstrated to be effective at building capacity. Learning-by-doing through substantive involvement in the execution of a climate change assessment was the most important component of the capacity building activities. Efforts were made to utilize the expertise of developing country participants to assist with training and capacity transfers to their colleagues. This worked well and even led to a number of training workshops organized by some of the teams for colleagues in other projects. A substantial portion of the capacity building resulted from the cross-project learning and sharing of methods, expertise, data and experiences.

Sustainable yet vulnerable capacity. The individual and institutional capacities built by AIACC show signs of being sustainable as all the teams are continuing to engage in the climate change issue. A number of factors contribute to this sustainability. First, the climate change assessments were executed by scientific institutions that have long-term commitments to research, education, and training related to climate change hazards and therefore possess a strong self-interest to further invest in and use the capacities enhanced by the AIACC project. Second, individual capacity building and training efforts were targeted to early-career scientists. As they develop capabilities to excel in this field, it is expected that many will focus future research, assessment, and policy activities to address problems of climate change. Third, the success that AIACC has found in developing cross-institutional collaborations and engagement of participants with IPCC, MEA, IAAST, and the global change research programs has developed networks that will serve to keep the individuals and institutions that participated in AIACC engaged in climate assessment work.

However, despite these positive signs, the enhanced capacity yielded by the project is vulnerable. Some of the assessment teams have succeeded in securing resources to continue working together on the problems of climate change and adaptation, and this will help to sustain their capacity. But many more have not. Without new resources to fund new efforts, the institutions that participated will invest their energies in pursuing opportunities in areas other than climate change; they will lose persons with relevant knowledge and skills; and their relationships with other institutions working on climate change will weaken from disuse. Further investments are needed by projects similar to AIACC to nurture and sustain the capacity in developing countries for advancing knowledge about climate change risks and applying new knowledge to better management of the risks.

Some new investments that build on the AIACC experience have already emerged. Advancing Capacity to Support Climate Change Adaptation (ACCCA) is bringing together scientists and stakeholders to communicate and apply knowledge of climate change risks in planning adaptation. Several of the AIACC teams are helping to provide the technical support for execution of the project. The ACCCA project is a joint initiative of START, the United Nations Institute for Training and Research and the Stockholm Environment Institute and is funded by the European Commission – EuropeAid Cooperation Office, the UK Department of Environment, Food and Rural Affairs, the International Development Research Centre (IDRC) and the ETC Foundation of the Netherlands. On a larger scale, the new Climate Change Adaptation in Africa (CCAA) program managed by IDRC is applying a model similar to AIACC to promote 'action research' that will build capacity for adaptation in Africa.

More investment is needed in developing country science. While new programs like ACCCA and CCAA are encouraging, a great deal more still needs to be done in developing countries to advance scientific knowledge about climate change vulnerability and adaptation. Progress will require further enhancement of scientific capacity in the developing world, both of institutions and people. But this need tends to fall between the responsibilities of development and science funding agencies. Bilateral and multilateral development assistance agencies, which have in the past supported science in developing countries related to climate change and global environmental change, are increasingly emphasizing adaptation projects that deliver tangible 'on the ground benefits' and are limiting research to very policy focused applications. Initiatives for tangible adaptation projects and highly policy focused research, while important and needed, allocate relatively small resources to expanding scientific knowledge and building scientific capacity. Meanwhile, science-funding agencies provide some support for science in developing countries, but have generally considered the development assistance agencies to have the primary responsibility in this area. There is a danger of a growing gap in funding for the underlying science and scientific capacity in developing countries that are essential for sustainable progress on reducing environmental and climate change threats. The International Group of Funding Agencies (IGFA) for global change research is aware of this gap and has initiated discussions with the development assistance community. But at present the prospects for adequate support of science capacity building do not look good.

References

Adejuwon, J.O. 2008. Vulnerability in Nigeria, a national level assessment. In N. Leary, C. Conde, J. Kulkarni, A. Nyong and J. Pulhin, eds., *Climate Change and Vulnerability*. Earthscan, London, UK.

Barros, V., A. Menéndez, C. Natenzon, R. Kokot, J. Codignotto, M. Re, P. Bronstein, I. Camilloni, S.G. González, D. Ríos and S. Ludueña. 2008. Climate change vulnerability to floods in the metropolitan region of Buenos Aires. In N. Leary, C. Conde, J. Kulkarni, A. Nyong and J. Pulhin, eds., *Climate Change and Vulnerability*. Earthscan, London, UK.

Batima, P., L. Natsagdorj, and N. Batnasan. 2008a. Vulnerability of Mongolia's pastoralists to climate extremes and change. In N. Leary, C. Conde, J. Kulkarni, A. Nyong and J. Pulhin, eds., *Climate Change and Vulnerability*. Earthscan, London, UK.

Batima, P., B. Bat, S. Tserendorj and B. Myagmarjav. 2008b. Adapting to drought, zud and climate change in Mongolia's rangelands. In N. Leary, J. Adejuwon, V. Barros, I. Burton, J. Kulkarni and R. Lasco eds., *Climate Change and Adaptation*. Earthscan, London, UK.

Burton, I. 2004. Climate Change and the Adaptation Deficit. In Adam Fenech, ed., *Climate Change: Building the Adaptive Capacity*. Papers from an International Conference on Adaptation Science, Management, and Policy Options. Lijiang, Yunnan, China, May 17 -19 2004. Meteorological Service of Canada, Environment Canada, Toronto.

Chinvanno, S., S. Boulidam, T. Inthavong, S. Souvannalath, B. Lersupavithnapa, V. Kerdsuk and N. Thuan. 2008a. Climate risks and rice farming in the lower Mekong River basin. In N. Leary, C. Conde, J. Kulkarni, A. Nyong and J. Pulhin, eds., *Climate Change and Vulnerability*. Earthscan, London, UK.

Chinvanno, S., S. Boulidam, S. Souvannalath, B. Lersupavithnapa, V. Kerdsuk and N. Thuan. 2008b. Strategies for managing climate risks in the lower Mekong River basin: a place based approach. In N. Leary, J. Adejuwon, V. Barros, I. Burton, J. Kulkarni and R. Lasco, eds., *Climate Change and Adaptation*. Earthscan, London, UK.

Conde, C., M. Vinocur, C. Gay, R. Seiler, and F. Estrada. 2008. Climatic threat spaces in Mexico and Argentina. In N. Leary, C. Conde, J. Kulkarni, A. Nyong and J. Pulhin, eds., *Climate Change and Vulnerability*. Earthscan, London, UK.

Dabi, D.D., A.O. Nyong, A.A. Adepetu, V. Ihemegbulem and J. Agaye. 2008. Past, present and future adaptation by rural households in northern Nigeria. In N. Leary, J. Adejuwon, V. Barros, I. Burton, J. Kulkarni and R. Lasco, eds., *Climate Change and Adaptation*. Earthscan, London, UK.

Dube, O.P., and M.B.M. Sekhwela. 2008. Indigenous knowledge, institutions and practices for coping with variable climate in the Limpopo Basin of Botswana. In N. Leary, J. Adejuwon, V. Barros, I. Burton, J. Kulkarni and R. Lasco. eds., *Climate Change and Adaptation*. Earthscan, London, UK.

Eakin, H., M. Wehbe, C. Avila, G.S. Torres, and L.A. Bojorquez-Tapia. 2008. Social vulnerability of farmers in Mexico and Argentina. In N. Leary, C. Conde, J. Kulkarni, A. Nyong and J. Pulhin, eds., *Climate Change and Vulnerability*. Earthscan, London, UK.

Heslop-Thomas, C., W. Bailey, D. Amarakoon. A. Chen, S. Rawlins, D. Chadee, R. Crosbourne, A. Owino, K. Polson, C. Rhoden, R. Stennett and M. Taylor. 2008. Vulnerability to dengue fever in Jamaica. In N. Leary, C. Conde, J. Kulkarni, A. Nyong and J. Pulhin, eds., *Climate Change and Vulnerability*. Earthscan, London, UK.

IPCC. 2007a. 'Summary for Policy Makers.' In S. Solomon, D. Qin, M. Manning, M. Marquis, K. Averyt, M. Tignor, H. Miller and Z. Chen, eds., *Climate Change 2007: The Physical Science Basis*. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK and New York, USA.

IPCC. 2007b. 'Summary for Policy Makers.' In M. Parry, O. Canziani, J. Palutikof, P.J. van der Linden and C. Hanson, eds., *Climate Change 2007: Impacts, Adaptation and Vulnerability*. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK and New York, USA.

Lasco, R., F. Pulhin, R. Cruz, J. Pulhin, S. Roy and P. Sanchez. 2008a. Forest responses to changing rainfall in the Philippines. In N. Leary, C. Conde, J. Kulkarni, A. Nyong and J. Pulhin, eds., *Climate Change and Vulnerability*. Earthscan, London, UK.

Lasco, R.D., R.V.O. Cruz, J.M. Puhlin and F.B. Puhlin. 2008b. Spillovers and tradeoffs of adaptation in the Pantabangan-Carrangalan watershed of the Philippines. In N. Leary, J. Adejuwon, V. Barros, I. Burton, J. Kulkarni and R. Lasco, eds., *Adaptation to Climate Change*. Earthscan, London, UK.

Leary, N., C. Conde, J. Kulkarni, A. Nyong and J. Pulhin, editors. 2008a. *Climate Change and Vulnerability*. Earthscan, London, UK.

Leary, N., J. Adejwon, V. Barros, I. Burton, J. Kulkarni and R. Lasco, editors. 2008b. *Climate Change and Adaptation*. Earthscan, London, UK.

Mataki, M., K. Koshy, R. Lata and L. Ralogaivau. 2005. Vulnerability of a coastal township to flooding associated with extreme rainfall events in Fiji', unpublished working paper, University of the South Pacific, Suva, Fiji.

Mataki, M., K. Koshy and V. Nair. 2008. Top-down, bottom up: mainstreaming adaptation in Pacific Island townships. In N. Leary, J. Adejuwon, V. Barros, I. Burton, J. Kulkarni and R. Lasco, eds., *Climate Change and Adaptation*. Earthscan, London, UK.

Mougou, R., A. Abou-Hadid, A. Iglesias, M. Medany, A. Nafti, R. Chetali, M. Mansour and H. Eid. 2008. Adapting dryland and irrigated cereal farming to climate change in Tunisia and Egypt. In N. Leary, J. Adejuwon, V. Barros, I. Burton, J. Kulkarni and R. Lasco, eds., *Climate Change and Adaptation*. Earthscan, London, UK.

Nagy, G.J., M. Bidegain, R.M. Caffera, J.J. Lagomarsino, W. Norbis, A. Ponce and G. Sencion. 2008. Fishing strategies for managing climate variability and change in the estuarine front of the Rio de la Plata. In N. Leary, J. Adejuwon, V. Barros, I. Burton, J. Kulkarni and R. Lasco, eds., *Climate Change and Adaptation*. Earthscan, London, UK.

Nyong, A., D. Dabi, A. Adepetu, A. Berthe, and V.C. Ihemegbulem. 2008. Vulnerability in the Sahelian zone of northern Nigeria, a household level assessment. In N. Leary, C. Conde, J. Kulkarni, A. Nyong and J. Pulhin, eds., *Climate Change and Vulnerability*. Earthscan, London, UK.

Osman-Elasha, B., and A. Sanjak. 2008. Livelihoods and drought in Sudan. In N. Leary, C. Conde, J. Kulkarni, A. Nyong and J. Pulhin, eds., *Climate Change and Vulnerability*. Earthscan, London, UK.

Osman-Elasha, B., N. Goutbi, E. Spranger-Siegfried, B. Dougherty, A. Hanafi, S. Zakieldeen, A. Sanjak, H. Atti and H.M. Elhassan. 2008. Community development and coping with drought in rural Sudan. In N. Leary, J. Adejuwon, V. Barros, I. Burton, J. Kulkarni and R. Lasco, eds., *Climate Change and Adaptation*. Earthscan, London, UK.

Payet, R.A. 2008. Climate change and the tourism dependent economy of the Seychelles. In N. Leary, C. Conde, J. Kulkarni, A. Nyong and J. Pulhin, eds., *Climate Change and Vulnerability*. Earthscan, London, UK.

Pulhin, J.M., R. Peras, R. Cruz, R. Lasco, F. Pulhin, and M. Tapia. 2008. Climate variability and extremes in the Pantabangan-Carranglan watershed of the Philippines, an assessment of vulnerability. In N. Leary, C. Conde, J. Kulkarni, A. Nyong and J. Pulhin, eds., *Climate Change and Vulnerability*. Earthscan, London, UK.

Sheppard, C., D.J. Dixon, M. Gourlay, A. Sheppard, and R. Payet. 2005. Coral mortality increases wave energy reaching shores protected by reef flats: examples from the Seychelles. *Estuarine, Coastal and Shelf Science* 64:223-234.

Taylor, M.A., A.A. Chen, S. Rawlins, C. Heslop-Thomas, A. Amarakoon, W. Bailey, D. Chadee, S. Huntley, C. Rhoden and R. Stennett. 2008. Adapting to dengue risk – what to do? In N. Leary, J. Adejuwon, V. Barros, I. Burton, J. Kulkarni and R. Lasco, eds., *Climate Change and Adaptation*. Earthscan, London, UK.

Travasso, M.I., G.O. Magrin, W.E. Baethgen, J.P. Castaño, G.R. Rodriguez, J.L. Pires, a. Gimenez, G. Cunha, and M. Fernandes. 2008. Maize and soybean cultivation in southeastern South America: adapting to climate change. In N. Leary, J. Adejuwon, V. Barros, I. Burton, J. Kulkarni and R. Lasco, eds., *Climate Change and Adaptation*. Earthscan, London, UK.

von Maltitz, G.P., and R.J. Scholes. 2008. Vulnerability of Southern African biodiversity to climate change. In N. Leary, C. Conde, J. Kulkarni, A. Nyong and J. Pulhin, eds., *Climate Change and Vulnerability*. Earthscan, London, UK.

von Maltitz, G.P., R.J. Scholes, B. Erasmus and A. Letsoalo. 2008. Adapting conservation strategies to climate change in South Africa. In N. Leary, J. Adejuwon, V. Barros, I. Burton, J. Kulkarni and R. Lasco, eds., *Climate Change and Adaptation*. Earthscan, London, UK.

Wandiga, S.O., M. Opondo, D. Olago, A. Githeko, F. Githui, M. Marshall, T. Downs, A. Opere, P.Z. Yanda, R. Kangalawe, R. Kabumbuli, J. Kathuri, E. Apindi, L. Olaka, L. Ogallo, P. Mugambi, R. Sigalla, R. Nanyunja, R. Baguma, and P. Achola. 2008. Vulnerability to climate induced highland malaria in East Africa. In N. Leary, C. Conde, J. Kulkarni, A. Nyong and J. Pulhin, eds., *Climate Change and Vulnerability*. Earthscan, London, UK.

Wehbe, M., H. Eakin, R. Seiler, M. Vinocur, C. Avila and C. Marutto. 2008. Local perspectives on adaptation to climate change: lessons from Mexico and Argentina. In N. Leary, J. Adejuwon, V. Barros, I. Burton, J. Kulkarni and R. Lasco, eds., *Climate Change and Adaptation*. Earthscan, London, UK.

Yanda, P.Z., Wandiga, S.O., Kangalawe, R.Y.M, Opondo, M., Olago, D., Githeko, A., Downs, T., Kabumbuli, R., Opere, A., Githui, F., Kathuri,J., Olaka, L., Apindi, E., Marshall, M., Ogallo, L., Mugambi, P., Kirumira, E., Nanyunja, R., Baguma, T., Sigalla, S., Achola, P. 2008. Climate, malaria and cholera in the Lake Victoria region: adapting to changing risks. In N. Leary, J. Adejuwon, V. Barros, I. Burton, J. Kulkarni and R. Lasco, eds., *Climate Change and Adaptation*. Earthscan, London, UK.

Yin, Y., N. Clinton, B. Luo, and L. Song. 2008a. Resource system vulnerability to climate stresses in the Heihe River basin of Western China. In N. Leary, C. Conde, J. Kulkarni, A. Nyong and J. Pulhin, eds., *Climate Change and Vulnerability*. Earthscan, London, UK.

Yin, Y., Z. Xu and A. Long. 2008b. Evaluation of adaptation options in the Heihe River Basin of China. In N. Leary, J. Adejuwon, V. Barros, I. Burton, J. Kulkarni and R. Lasco, eds., *Climate Change and Adaptation*. Earthscan, London, UK.

Ziervogel, G., A. Nyong, B. Osman-Elasha, C. Conde, T.E. Downing, and Cortés, S. 2008. Household food security and climate change: comparisons from Nigeria, Sudan, South Africa and Mexico. In N. Leary, C. Conde, J. Kulkarni, A. Nyong and J. Pulhin, eds., *Climate Change and Vulnerability*. Earthscan, London, UK.

Table S.1: AIACC Climate Change Assessments in Africa

Project No.	Project Title	Administering Institution and Principal Investigator	Countries	Award Amt. (US$)	Co-funding (US$)
AF04	Impacts and Adaptations to Climate change in the Biodiversity Sector in Southern Africa	CSIR, Division of Water, Environment and Forest Technology, South Africa. Dr. Robert Scholes.	South Africa	195,000	104,200
AF07	High Resolution Regional Climate Change Scenarios for Sub-Saharan Africa	Climate System Analysis Group, Univeristy of Cape Town, South Africa. Dr. Bruce Hewitson.	South Africa, Ghana, Nigeria, Senegal, Zambia and Zimbabwe (scenarios developed for Sub-Saharan Africa)	169,995	
AF14	Environmental Strategies to Increase Human Resilience to Climate Change: Lessons for North and East Africa	Higher Council for Environment and Natural Resources, Sudan. Dr. Balgis Osman-Elasha and Nagmeldin Goutbi Elhassan.	Sudan	150,000	12,000
AF20	Assessing Global And Regional Climate Change Scenarios for West Africa	Laboratory for Atmospheric Physics, Cheik Anta Diop University, Senegal. Dr. Amadou Gaye.	Senegal (scenarios developed for West Africa)	100,000	15,000
AF23	Food Security, Climate Variability and Climate Change in Sub-Saharan West Africa	Department of Geography, Obafemi Awolowo University, Nigeria. Dr. James Adejuwon.	Nigeria	180,000	56,000
AF38	Integrated Assessment of Miombo Region: Exploration of Impacts and Adaptation Options in Relation to Climate Change and Extremes	Centro Nacional de Cartografica e Teledeteccao, Mozambique. Dr. Manuel Ferrao and Dr. Paul Desanker.	Malawi, Mozambique, Zambia, Zimbabwe	215,628	37,000
AF42	Impacts of Climate Change, Vulnerability and Adaptation Capacity in the Limpopo Basin of Semi-Arid Land Southern Africa: The Case of Eastern Botswana	Department of Environmental Science, University of Botswana. Dr. Pauline Dube.	Botswana	195,000	
AF47	Estimating Costs and Benefits of Adaptation Projects: Examples from South Africa and the Gambia	Energy and Development Research Center, University of Cape Town. Dr. J.C. Nkomo and Dr. Bubu Jallow.	South Africa and The Gambia	150,000	105,000
AF90	Assessment of Impacts, Adaptation and Vulnerability to Climate Change in North Africa: Food Production and Water Resources	Central Laboratory for Agricultural Climate, Egypt. Dr. Ayman Abou-Hadid.	Egypt and Tunisia	190,000	
AF91	Climate Change Induced Vulnerability to Malaria and Cholera in the Lake Victoria Region	National Academy of Sciences of Kenya. Dr. Shem Wandiga.	Kenya, Tanzania and Uganda	225,000	
AF92	Rural Households and Drought in the Sahel Region of West Africa: Vulnerability and Effective Mitigation Measures	Center for Environmental Resources and Hazards Research, Department of Geography and Planning, University of Jos, Nigeria. Dr. A.A. Adepetu and Dr. Anthony Nyong.	Mali, Nigeria	224,500	50,000

Table S.2: AIACC Climate Change Assessments in Asia

Project No.	Project Title	Administering Institution and Principal Investigator	Countries	Award Amt. (US$)	Co-funding (US$)
AS06	Climate Change Vulnerability and Adaptation in the Livestock Sector of Mongolia	Institute of Hydrology and Meteorology, Mongolia. Dr. Punsalmaa Batima.	Mongolia	210,000	99,958
AS07	Rain-fed Rice Farming, Climate Change and Climate Extremes in Southeast Asia	Southeast Asia START Regional Center, Chulalongkorn University, Thailand. Dr. Anond Snidvongs.	Thailand, Lao PDR and Vietnam	158,000	49,000
AS12	Assessment of the Impacts of and Adaptations to Climate Change in the Coconut and Tea Plantation Sectors	Sri Lanka Association for the Advancement of Science, Sri Lanka. Dr. Janaka Ratnasiri.	Sri Lanka	194,985	90,000
AS21	An Integrated Assessment of Climate Impacts, Adaptations, and Vulnerability in Watershed Areas and Communities in Southeast Asia	University of the Philippines at Los Banos, College of Forestry and Natural Resources, Philippines. Dr. Rodel Lasco.	Philippines and Indonesia	150,000	87,120
AS25	Vulnerability and Adaptation to climate Variability and change in Western China	International Earth System Sciences Institute at Nanjing University, PR of China, and Sustainable Development Research Institute at the University of British Columbia, Canada. Dr. Yongyuan Yin.	People's Republic of China	185,000	238,000

Table S.3: AIACC Climate Change Assessments in Latin America

Project No.	Project Title	Administering Institution and Principal Investigator	Countries	Award Amt. (US$)	Co-funding (US$)
LA06	Impacts and Adaptation to Climate Change and Extreme Events in Central America	Laboratory for Atmospheric and Planetary Research, School of Physics, University of Costa Rica, Costa Rica. Dr. Walter Fernandez.	Guatemala, Belize, El Salvador, Honduras, Nicaragua, Costa Rica and Panama	195,000	50,000
LA26	Global Climate Change and the Coastal Areas of the Río de la Plata	Department of Atmospheric and Ocean Sciences, University of Buenos Aires, Argentina. Dr. Vicente Barros.	Argentina and Uruguay	100,000	100,000
LA27	Climate Change and Variability in the Mixed Crop / Livestock Production Systems of the Argentinean, Brazilian and Uruguayan Pampas	Instituto Nacional de Investigacion Agropecuaria, Uruguay. Dr. Agustin Gimenez.	Uruguay, Argentina and Brazil	274,370	228,000
LA29	Vulnerability and Adaptation to Climate Variability and Change: The Case of Farmers in Mexico and Argentina	Center for Atmospheric Sciences, Autonomous National University of Mexico, Mexico. Dr. Carlos Guy and Dr. Cecilia Conde.	Argentina and Mexico	210,000	176,100
LA32	Vulnerability and Adaptation of Estuarine Systems of the Río de la Plata	Department of Ecology, University of the Republic, Uruguay. Dr. Gustavo Nagy.	Uruguay and Argentina	100,000	60,000

Table S.4: AIACC Climate Change Assessments in Small Island States

Project No.	Project Title	Administering Institution and Principal Investigator	Countries	Award Amt. (US$)	Co-funding (US$)
SIS06	The Threat of Dengue Fever in the Caribbean	Department of Physics, University of the West Indies, Jamaica and the Caribbean Epidemiology Center, Trinidad and Tobago. Dr. Anthony Chen and Dr. Samuel Rawlins.	Jamaica, St. Kitts and Nevis, Trinidad and Tobago and of the members of the Caribbean Epidemiology Center	218,250	86,000
SIS09	Modeling Climate Change Impacts on Viti Levu (Fiji) and Aitutaki (Cook Islands) (SIS09)	Pacific Center for Environment and Sustainable Development, University of the South Pacific. Dr. Kanayathu Koshy.	Fiji and Cook Islands	220,000	150,000
SIS90	Impact of Climate Change on Tourism in Seychelles and Comoros (SIS90)	Climate Centre, Ministry of Environment, Seychelles. Dr. Rolph Payet.	Seychelles and Comoros	224,984	30,000

1 Introduction

1.1 Project Needs, Objectives and Support

Vulnerability to climate change is high in much of the developing world. Social, economic and environmental conditions amplify susceptibility to negative impacts and constrain the capacity to cope with climate hazards. Because of the high level of vulnerability, there exists an urgent need in developing countries to formulate and implement adaptive strategies that would lessen climate change risks. However, the Third Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) demonstrated that, at the time of publication of the report, information about vulnerability to adverse impacts and adaptation options was very limited for important sectors and systems in developing countries, that many developing countries lacked adequate capacity to systematically evaluate impacts and adaptation options, and that these conditions significantly constrained effective adaptation responses.

To address the gaps in knowledge and scientific capacity, the IPCC collaborated with the United Nations Environment Programme (UNEP), the global change SysTem for Analysis, Research, and Training (START) and the Academy of Sciences for the Developing World (TWAS) to develop a proposal for the global project Assessments of Impacts of and Adaptation to Climate Change in Multiple Regions and Sectors (AIACC). The project had three objectives:

- Enhance scientific capacity in developing countries to assess climate change impacts, vulnerability, and adaptation;
- Advance scientific understanding of these issues; and
- Improve links between climate change science and policy communities to enable adaptation planning and action.

Outcomes achieved by the project include enhanced capabilities for multidisciplinary assessment of climate change of 24 developing country teams composed of more than 350 scientists, stakeholders and students; engagement of the teams in the IPCC 4th Assessment Report and other international science and policy activities; publication of more than 100 peer-reviewed papers; establishment of working relationships among scientific, stakeholder and policy institutions in each of the study regions; and contributions of new knowledge and capacity to support National Communications to the United Nations Framework Convention on Climate Change (UNFCCC).

The AIACC project was funded by the Global Environmental Facility (GEF) as an enabling activity in the climate change focal area with a grant of US$7,5000,000. Financial support was also received from the Canadian International Development Agency (US$100,000), the United States Agency for International Development (US$300,000), the United States Environmental Protection Agency (US$50,000) and the Rockefeller Foundation (US$25,000). Participating developing country institutions provided in-kind co-funding valued at US$1,800,000.

1.2 Overview of Activities and Results

The primary activity of the AIACC project was the execution of twenty-four climate change assessments in Africa, Asia, Latin America and the Caribbean, Indian and Pacific Oceans by developing country institutions, scientists and experts. Through execution of the assessments, the project enhanced scientific and technical capacity of the participating institutions and individuals, advanced scientific understanding and forged links between scientific institutions, key stakeholder organizations, and agencies responsible for policies related to climate change and the management of climate hazards. The climate change assessments were supported with a comprehensive program of capacity building and networking that included 'learning-by-doing,' technical assistance, training, regional science and policy workshops and engagement in international science and policy activities. The climate change assessment teams also participated in synthesis activities to derive common lessons from the individual assessments. More than 350 scientists, stakeholders and students from 150 institutions in 50 developing countries and 12 developed countries participated in the regional assessments, capacity building, networking and synthesis activities (see Annex B for a list of participating institutions). In addition, numerous stakeholders in each of the assessment regions also participated.

The AIACC regional climate change assessments were selected on the basis of merit review of proposals submitted to AIACC. Preliminary proposals were invited in 2001 through a widely advertised call that was open to scientific, research and other institutions of developing countries. Preliminary proposals were received from 148 applicants. The AIACC Technical Committee reviewed the preliminary proposals and invited full proposals from 54 teams. The full proposals were evaluated by external reviewers for scientific and technical quality, capabilities of the proposal team, and relevance to the objectives of AIACC. Based upon the reviews, and taking into consideration additional criteria of geographic balance, priority sectors and systems, and policy relevance, the Technical Committee made recommendations to the Implementing Committee, which then made decisions on awards. The decisions were submitted to the project Steering Committee for concurrence, which endorsed the decisions. Decisions were announced at the end of 2001 and awards made after the assessment projects received endorsements from GEF national focal points.

Twenty-four climate change assessments were selected for awards, which included 11 in Africa, 5 in Asia, 5 in Latin America and 3 in small island states. The regional distribution of assessments selected for awards conformed to the original intent to focus most heavily on Africa. The climate change assessments, launched in early 2002, were led and executed by multidisciplinary and multi-institutional teams of experts and stakeholders from the countries that were the focus of the assessments. All 24 of the climate change assessments were completed by the end of 2005. The titles, administering institutions, participating countries and grant amounts are detailed in the tables at the end of this chapter.

A technical advisor was assigned to each climate change assessment to provide general guidance, technical assistance and referrals to other sources of expertise when needed. Three global training workshops were held in 2002 to provide training in methods and tools for assessment of climate change vulnerability and adaptation, including methods for construction and use of climate change scenarios. Six regional workshops were held in 2003-2004, two each in Africa, Asia-Pacific and Latin America-Caribbean to provide opportunities for cross-team learning, sharing of methods, and networking with each other and regional stakeholders. Each of the climate change assessment teams also organized and implemented additional capacity building and stakeholder engagement activities in 2004 and 2005 targeted to their specific needs, which included a number of south-south training activities. The AIACC project facilitated the participation of developing country scientists and experts in international science and policy activities by organizing sessions at science conferences and side events at the UNFCCC Conference of the Parties, sponsoring participation in conferences and meetings, and nominating individuals to be authors of the 4^{th} Assessment Report of the IPCC, participants in expert meetings of the UNFCCC SBSTA, and presenters in other international meetings.

Evidence of the effectiveness of AIACC capacity building and networking activities is given by the high scientific output of the assessments, the extensive participation of AIACC investigators in the IPCC, new south-south capacity building activies spawned by AIACC, and AIACC participants taking leadership roles in the climate change science and adaptation community. The assessments have produced to date more than 60 papers in peer-reviewed journals and books, over 40 papers in the on-line peer-reviewed *AIACC Working Papers* series, two book manuscripts to be published in late 2007 by Earthscan and numerous other publications, including 25 student theses. There are more than 100 citations of AIACC publications in the new IPCC 4^{th} Assessment Report. Findings from the assessments are being incorporated into national communications to the UNFCCC, providing input to new research and assessment activities, and informing adaptation planning efforts.

1.3 Project Management

The global change SysTem for Analysis, Research and Training (START) and the Academy of Sciences for the Developing World (TWAS) are the executing agencies of the AIACC project. The United Nations Environment Programme (UNEP) acted as the implementing agency. Mohamed Hassan of TWAS, Neil

Leary of START and a representative of UNEP – initially Ravi Sharma, then Mahendra Kumar and finally Liza Leclerc – formed the project Implementing Committee, which was responsible for joint management of the project. General oversight was provided by the AIACC Steering Committee, composed of Bonnie Biagini (GEF Secretariat), Osvaldo Canziani (IPCC Working Group II Co-Chair), David Carson (WCRP, ex-officio), Renate Christ (IPCC Secretary), Raul Estrada (SBI Chair), Barbara Goebel (IHDP, ex-officio), Saleemul Huq (GEF-STAP), Bo Lim (UNDP), Ajay Mathur (World Bank), Rajendra Pachauri (IPCC Chair), Martin Parry (IPCC Working Group II Co-Chair), Martha Perdomo (UNFCCC Secretariat), Will Stefen (IGBP, ex-officio), Haldor Thorgeirsson (SBSTA Chair) and Robert Watson (the World Bank).

The AIACC Technical Committee provided technical advice about the review and selection of climate change assessments, assessment methods and tools, design and implementation of the technical assistance and capacity building program, and review of project outputs. Members of the Technical Committee include Ian Burton (University of Toronto, Canada), Max Campos (CRRH, Costa Rica), Tom Downing (SEI, UK), Saleemul Huq (IIED, UK/Bangladesh), Jill Jaeger (IHDP), Richard Klein (PIK, Germany), Isabelle Niang-Diop (ENDA, Senegal), Hideo Harasawa (NIES, Japan), Mike Hulme (Tyndall Centre, UK), Murari Lal (IIT, India), Linda Mearns (NCAR, USA), Carlos Nobre (CPTEC/INPE, Brazil), Annand Patwardhan (IITB, India), Robert Scholes (CSIR, South Africa) and Penny Whetton (CSIRO, Australia). Members of the Technical Committee, as well as Paul Desanker (PSU, USA/Malawi), Bruce Hewitson (UCT, South Africa), Roger Jones (CSIR, Australia), Xianfu Lu (Tyndall Centre, UK/China) and Jose Marengo (CPTEC/INPE, Brazil), acted as technical advisors to the AIACC climate change assessments.

The AIACC Science Director, Neil Leary, assisted by Patricia Presiren of TWAS and Sara Beresford, Laisha Said-Moshiro, Jyoti Kulkarni and Kathy Landauer of START, managed execution of the project. Execution of the regional climate change assessments was coordinated by their respective Principal Investigators, who are named in the tables at the end of the chapter.

1.4 Guide to the Rest of the Report

Chapter 2 of the report presents a synthesis of research findings and lessons from the 24 assessments about climate change vulnerability, while Chapter 3 presents a synthesis of findings about adaptation. The activities and results of each of the Africa region assessments are summarized in Chapter 4, the Asia region assessments in Chapter 5, the Latin American assessments in Chapter 6, and the assessments for Small Island States in Chapter 7.[3] Capacity building activities implemented to support the assessments are described in Chapter 8 and project outputs and their uses are summarized in Chapter 9. Performance with respect to the project objectives and intended outcomes is evaluated in Chapter 10. The final chapter, Chapter 11, presents conclusions and recommendations.

This report of the AIACC project represents only one of the many outputs of the project. A complete listing of peer-reviewed and other publications and outputs from the project appears in Annex A of the report. The institutions and countries that participated in AIACC are listed in Annex B.

[3] Comprehensive final reports from each of the assessments are available on-line at http://aiaccproject.org.

Table 1.1: AIACC Climate Change Assessments in Africa

Project No.	Project Title	Administering Institution and Principal Investigator	Countries	Award Amt. (US$)	Co-funding (US$)
AF04	Impacts and Adaptations to Climate change in the Biodiversity Sector in Southern Africa	CSIR, Division of Water, Environment and Forest Technology, South Africa. Dr. Robert Scholes.	South Africa	195,000	104,200
AF07	High Resolution Regional Climate Change Scenarios for Sub-Saharan Africa	Climate System Analysis Group, Univeristy of Cape Town, South Africa. Dr. Bruce Hewitson.	South Africa, Ghana, Nigeria, Senegal, Zambia and Zimbabwe (scenarios developed for Sub-Saharan Africa)	169,995	
AF14	Environmental Strategies to Increase Human Resilience to Climate Change: Lessons for North and East Africa	Higher Council for Environment and Natural Resources, Sudan. Dr. Balgis Osman-Elasha and Nagmeldin Goutbi Elhassan.	Sudan	150,000	12,000
AF20	Assessing Global And Regional Climate Change Scenarios for West Africa	Laboratory for Atmospheric Physics, Cheik Anta Diop University, Senegal. Dr. Amadou Gaye.	Senegal (scenarios developed for West Africa)	100,000	15,000
AF23	Food Security, Climate Variability and Climate Change in Sub-Saharan West Africa	Department of Geography, Obafemi Awolowo University, Nigeria. Dr. James Adejuwon.	Nigeria	180,000	56,000
AF38	Integrated Assessment of Miombo Region: Exploration of Impacts and Adaptation Options in Relation to Climate Change and Extremes	Centro Nacional de Cartografica e Teledeteccao, Mozambique. Dr. Manuel Ferrao and Dr. Paul Desanker.	Malawi, Mozambique, Zambia, Zimbabwe	215,628	37,000
AF42	Impacts of Climate Change, Vulnerability and Adaptation Capacity in the Limpopo Basin of Semi-Arid Land Southern Africa: The Case of Eastern Botswana	Department of Environmental Science, University of Botswana. Dr. Pauline Dube.	Botswana	195,000	
AF47	Estimating Costs and Benefits of Adaptation Projects: Examples from South Africa and the Gambia	Energy and Development Research Center, University of Cape Town. Dr. J.C. Nkomo and Dr. Bubu Jallow.	South Africa and The Gambia	150,000	105,000
AF90	Assessment of Impacts, Adaptation and Vulnerability to Climate Change in North Africa: Food Production and Water Resources	Central Laboratory for Agricultural Climate, Egypt. Dr. Ayman Abou-Hadid.	Egypt and Tunisia	190,000	
AF91	Climate Change Induced Vulnerability to Malaria and Cholera in the Lake Victoria Region	National Academy of Sciences of Kenya. Dr. Shem Wandiga.	Kenya, Tanzania and Uganda	225,000	
AF92	Rural Households and Drought in the Sahel Region of West Africa: Vulnerability and Effective Mitigation Measures	Center for Environmental Resources and Hazards Research, Department of Geography and Planning, University of Jos, Nigeria. Dr. A.A. Adepetu and Dr. Anthony Nyong.	Mali, Nigeria	224,500	50,000

Table 1.2: AIACC Climate Change Assessments in Asia

Project No.	Project Title	Administering Institution and Principal Investigator	Countries	Award Amt. (US$)	Co-funding (US$)
AS06	Climate Change Vulnerability and Adaptation in the Livestock Sector of Mongolia	Institute of Hydrology and Meteorology, Mongolia. Dr. Punsalmaa Batima.	Mongolia	210,000	99,958
AS07	Rain-fed Rice Farming, Climate Change and Climate Extremes in Southeast Asia	Southeast Asia START Regional Center, Chulalongkorn University, Thailand. Dr. Anond Snidvongs.	Thailand, Lao PDR and Vietnam	158,000	49,000
AS12	Assessment of the Impacts of and Adaptations to Climate Change in the Coconut and Tea Plantation Sectors	Sri Lanka Association for the Advancement of Science, Sri Lanka. Dr. Janaka Ratnasiri.	Sri Lanka	194,985	90,000
AS21	An Integrated Assessment of Climate Impacts, Adaptations, and Vulnerability in Watershed Areas and Communities in Southeast Asia	University of the Philippines at Los Banos, College of Forestry and Natural Resources, Philippines. Dr. Rodel Lasco.	Philippines and Indonesia	150,000	87,120
AS25	Vulnerability and Adaptation to climate Variability and change in Western China	International Earth System Sciences Institute at Nanjing University, PR of China, and Sustainable Development Research Institute at the University of British Columbia, Canada. Dr. Yongyuan Yin.	People’s Republic of China	185,000	238,000

Table 1.3: AIACC Climate Change Assessments in Latin America

Project No.	Project Title	Administering Institution and Principal Investigator	Countries	Award Amt. (US$)	Co-funding (US$)
LA06	Impacts and Adaptation to Climate Change and Extreme Events in Central America	Laboratory for Atmospheric and Planetary Research, School of Physics, University of Costa Rica, Costa Rica. Dr. Walter Fernandez.	Guatemala, Belize, El Salvador, Honduras, Nicaragua, Costa Rica and Panama	195,000	50,000
LA26	Global Climate Change and the Coastal Areas of the Río de la Plata	Department of Atmospheric and Ocean Sciences, University of Buenos Aires, Argentina. Dr. Vicente Barros.	Argentina and Uruguay	100,000	100,000
LA27	Climate Change and Variability in the Mixed Crop / Livestock Production Systems of the Argentinean, Brazilian and Uruguayan Pampas	Instituto Nacional de Investigacion Agropecuaria, Uruguay. Dr. Agustin Gimenez.	Uruguay, Argentina and Brazil	274,370	228,000
LA29	Vulnerability and Adaptation to Climate Variability and Change: The Case of Farmers in Mexico and Argentina	Center for Atmospheric Sciences, Autonomous National University of Mexico, Mexico. Dr. Carlos Guy and Dr. Cecilia Conde.	Argentina and Mexico	210,000	176,100
LA32	Vulnerability and Adaptation of Estuarine Systems of the Río de la Plata	Department of Ecology, University of the Republic, Uruguay. Dr. Gustavo Nagy.	Uruguay and Argentina	100,000	60,000

Table 1.4: AIACC Climate Change Assessments in Small Island States

Project No.	Project Title	Administering Institution and Principal Investigator	Countries	Award Amt. (US$)	Co-funding (US$)
SIS06	The Threat of Dengue Fever in the Caribbean	Department of Physics, University of the West Indies, Jamaica and the Caribbean Epidemiology Center, Trinidad and Tobago. Dr. Anthony Chen and Dr. Samuel Rawlins.	Jamaica, St. Kitts and Nevis, Trinidad and Tobago and of the members of the Caribbean Epidemiology Center	218,250	86,000
SIS09	Modeling Climate Change Impacts on Viti Levu (Fiji) and Aitutaki (Cook Islands) (SIS09)	Pacific Center for Environment and Sustainable Development, University of the South Pacific. Dr. Kanayathu Koshy.	Fiji and Cook Islands	220,000	150,000
SIS90	Impact of Climate Change on Tourism in Seychelles and Comoros (SIS90)	Climate Centre, Ministry of Environment, Seychelles. Dr. Rolph Payet.	Seychelles and Comoros	224,984	30,000

2 For Whom the Bell Tolls: Lessons about Climate Change Vulnerability from the AIACC Project

Authors: N. Leary, J. Adejuwon, W. Bailey, V. Barros, M. Caffera, S. Chinvanno, C. Conde, A. De Comarmond, A. De Sherbinin, T. Downing, H. Eakin, A. Nyong, M. Opondo, B. Osman-Elasha, R. Payet, F. Pulhin, J. Ratnasiri, E. Sanjak, G. von Maltitz, M. Wehbe, Y. Yin and G. Ziervogel

> *No man is an island, entire of itself; every man is a piece of the continent, a part of the main. If a clod be washed away by the sea, Europe is the less, as well as if a promontory were, as well as if a manor of thy friend's or of thine own were: any man's death diminishes me, because I am involved in mankind, and therefore never send to know for whom the bell tolls; it tolls for thee.(*John Donne, 1623).

2.1 Introduction

People have evolved ways of earning livelihoods and supplying their needs for food, water, shelter and other goods and services that are adapted to benefit from the climates in which they live. But the climate is ever variable and changeable, and deviations that are too far from the norm can be disruptive, even hazardous.

Now the climate is changing due to human actions. Despite efforts to abate the human causes, it will continue to change at least for decades, albeit at a slower and, we hope, less dangerous pace (IPCC, 2001a). Who is vulnerable to the changes and their impacts? For whom does the bell toll? We ask, against the oft quoted advice of the 17th century poet John Donne, because understanding who is vulnerable, and why, can help us to prevent our neighbors' home from washing into the sea, their family from suffering hunger, a child from being exposed to disease, the natural world around us from being impoverished. All of us are vulnerable to climate change, though to varying degrees, directly and through our connections to each other.

The propensity of people or systems to be harmed by stresses, referred to as vulnerability, is determined by their exposures to stresses, their sensitivity to the exposures, and their capacities to resist, cope with, exploit, recover from and adapt to the effects. Global climate change is bringing changes in exposures to climate stresses. The impacts will depend in part on the nature, rate and severity of the changes in climate. They will also depend to an important degree on social, economic, governance and other forces that determine who and what are exposed to climate stresses, their sensitivities to stresses, and their capacities. For some, the impacts may be beneficial. But predominantly harmful impacts are expected for much of the developing world (IPCC, 2001b).

To explore vulnerabilities to climate change and response options in developing country regions, twenty-four regional assessments were implemented under the international project Assessments of Impacts and Adaptations to Climate Change (AIACC). The AIACC case studies were not selected to comprehensively assess all vulnerabilities and systematically identify the places and systems that are most vulnerable. Still, the case studies do span a wide range of places and systems from which some general conclusions can be drawn. Our studies are placed in Africa, Asia, Latin America and islands of the Caribbean, Indian and Pacific Oceans. They include investigations of agriculture, pastoral systems, water resources, terrestrial and estuarine ecosystems, biodiversity, urban flood risks, coastal settlements, food security, livelihoods and human health.

Investigators from the AIACC case studies met at the Bellagio Study and Conference Center of the Rockefeller Foundation in March 2005 and again in Naivasha, Kenya in September 2005 to discuss compare and synthesize their findings. A number of generalized lessons emerged from the synthesis of the AIACC case studies. Lessons about vulnerability to climate change are presented here in this chapter, while lessons concerning adaptation are developed in Chapter 3 of the report. The protocol followed for the vulnerability synthesis is descrbied in Section 2.2. An overview of the vulnerability lessons is presented in Section 2.3 and subsequent sections of the chapter develop the lessons in more detail.

While general lessons are useful, vulnerability and adaptation capacity and options are highly context specific and many rich details are lost in the synthesis and search for commonalities. More complete treatments of the context specific details and lessons from the individual case studies can be found in *Climate Change and Vulnerability* (Leary et al, 2008a) and *Climate Change and Adaptation* (Leary et al, 2008b).

2.2 A Protocol for Vulnerability Synthesis

The case studies are varied in their objectives, the systems and sectors that are investigated, the methods that are applied, and their location specific contexts. The variety poses a problem for comparing and synthesizing findings from the different studies. But one factor that is common to each of the studies that participated in this synthesis is that they include investigation of the vulnerability of people, places or systems to climatic stresses.

Vulnerability studies take a different approach from investigations of climate change impacts, which generally emphasize quantitative modeling to simulate the impacts of selected climate change scenarios on Earth systems and people. In contrast, vulnerability studies focus on the processes that shape the consequences of climate variations and change to identify the conditions that amplify or dampen vulnerability to adverse outcomes. The climate drivers are treated as important in vulnerability studies, but drivers related to demographic, social, economic and governance processes are given equal attention. Consequently, existing vulnerabilities to current climate variations and extremes are examined for the insights they can provide regarding vulnerability to future climate change. A motivation for this approach is that it can help to highlight where interventions might reduce vulnerability most effectively (Leary, 2002).

Our synthesis of vulnerability lessons from the AIACC case studies was developed using a three step risk assessment protocol that has been previously applied by Downing (2002) to studies of food security. The protocol was implemented by a group of investigators from the AIACC case studies during a week long workshop held in March 2005.

The first step of the protocol was to develop contexts or domains of climate change vulnerability that correspond to resources or systems that are important to human wellbeing, are potentially affected by climate change, and are a focus of one or more of the case studies. The domains that emerged from the synthesis workshop are natural resources, coastal areas and small islands, rural economy and food security, and human health. In the second step, outcomes of concern within each domain were identified and ranked as low, medium or high level concerns. In selecting and ranking outcomes, we attempted to take the perspective of stakeholders concerned about national scale risks. Outcomes are included that our studies, and our interpretation of related literature, suggest are plausible and that, should they occur, would be of national significance. Our rankings of low, medium and high level concerns are based upon the following criteria: potential to exceed coping capacities of affected systems, the geographic extent of damages, the severity of damages relative to national resources, and the persistence or reversibility of the impacts. The rankings do not take into account the likelihood that an outcome would be realized. They represent the degree of concern that would result if the hypothesized outcomes do materialize. While we have not formally assessed the likelihood of the different outcomes, each is a potential result under plausible scenarios and circumstances.

In step three, we identified the climatic and non-climatic factors that create conditions of vulnerability to the outcomes of concern within each domain. Where climatic and non-climatic drivers combine to strongly amplify vulnerability, the potential for high-level concern outcomes being realized is greatest. Conversely, where some of the drivers interact to dampen vulnerability, outcomes of lower level concern are likely to result.

2.3 Overview of Lessons About Vulnerability

The AIACC regional assessments illustrate that vulnerability to adverse impacts from climate variation and change has multiple causes. The causes include climatic stresses as well as stresses that derive from interactions among environmental, demographic, social, economic, institutional, cultural, and technological processes. The state and dynamics of these processes differ from place to place and generate conditions of vulnerability that differ in character and degree. Consequently, populations that are exposed to similar climatic phenomena are not impacted the same. The most severe impacts that are of greatest concern generally are not expected to arise from climate stresses alone. Instead, such impacts are more likely when multiple stresses (climatic and non-climatic) interact to create conditions of high vulnerability. Some of the potential outcomes identified as high-level concerns and factors found to give rise to differences in vulnerability are described below.

Climate variability, extremes and change are a danger now, not just in the distant future. In each of the AIACC study areas, climate variations and extremes are immediate sources of risk. Climate hazards cause substantial damages such as loss of food and water supplies, reduced incomes, damaged homes and infrastructure, disruption of economic activity, degraded natural resources, disease outbreaks and loss of life. Global climate change is already occurring, has impacted natural and human systems, and now threatens to amplify the dangers.

The danger is greatest where natural systems are severely degraded and human systems are failing. Natural resource systems that are severely degraded from overuse are highly sensitive to climate variations and have diminished resilience. Climate shocks can cause large and persistent losses of the goods and services from these degraded systems. Failing social, economic and governance systems typically cannot respond effectively to manage pressures on natural resources, cope with the impacts of climate and other shocks on their resource base, or adapt to the changing conditions. It is in contexts such as these, exemplified by AIACC case studies in Sudan and Nigeria, in which the state of natural and human systems combine to create conditions of high vulnerability. Communities that are highly dependent on degraded resources and for which human systems are in or near a failed state are at greatest risk of worst-case outcomes such as collapse of rural livelihoods, deepening and widening poverty, displacement of population, hunger and famine, epidemics and violent conflict.

A corollary to this finding is that restoring and protecting natural systems and improving the performance of human systems can reduce vulnerability. The AIACC studies suggest that the potential severity and risk of many climate change outcomes are less where social, economic, and governance systems function in ways that enable effective responses to prevent, cope with, recover from and adapt to adverse impacts. Optimism ought to be tempered, however, by the reality of how challenging it has been to achieve even minimal progress where key human systems are dysfunctional.

Both heightened water scarcity and increased flood risks are critical concerns. Population and economic growth are increasing water demands and many parts of the world are expected to face water stresses that will constrain their development to an increasing degree. Climate change could either relieve or exacerbate water stress, depending on location and season, by increasing or decreasing water balances. While robust results for changes in annual and seasonal precipitation are emerging from climate models for some regions, for much of the world there continues to be high uncertainty about precipitation changes in the future. Given this uncertainty, results from AIACC studies are indicative of sensitivities and vulnerabilities to changes in water balances, but firm conclusions about likely outcomes require further study for most regions.

Climate change projections indicate the potential for drier future climates in AIACC study areas in southern Africa, the Sudano-Sahel zone and central Asia that would negatively impact water supplies, ecosystems, biodiversity, food security, rural economies, human health and economic development. These impacts, if sufficiently severe, would retard progress toward Millennium Development goals. Vulnerability to adverse impacts from reduced water balances depends on many factors including the level and growth rate of water demand relative to reliable supply; water and land use policies; planning and management; water infrastructure; and the distribution and security of water rights.

In contrast, increases in average precipitation are suggested by many of the climate models for study sites in southeastern South America, the lower Mekong River basin, the Philippines and Indonesia. For these areas, climate change may relieve water stress. But higher average rainfall, coupled with increases in intense rainfall events, also pose greater risks of flooding. Factors that exacerbate flood risks include growth in population and infrastructure in flood prone locations; exposure to coastal storm surge; poorly managed land use change; clearing of vegetation; filling of wetlands; and ineffective disaster prevention, preparedness, warning and response systems.

Land degradation may worsen in regions that become drier. Land degradation, an amplifier of vulnerability to climate change, is also a potential outcome of climate change. It is already a problem on intensively used marginal lands in AIACC study areas in arid parts of northwestern China, Mongolia, Mexico, Botswana, Nigeria, South Africa and Sudan. Land use pressures from population growth and economic forces will build if current land use policies and incentives continue unchanged. If combined with a drier climate and increased frequency, severity and duration of droughts, the likelihood of more widespread and persistent land degradation would be high. Exacerbation of land degradation by climate change would harm human well-being and pose obstacles to development by decreasing land productivity, diminishing incomes, depleting resources for coping and adapting and eroding the resilience of the land and land-based livelihoods.

The livelihoods and food security of the rural poor are threatened by climate change. Rural economies, which are based on and dominated by agricultural, pastoral and forest production, are highly sensitive to climate variations and change. So too are the livelihoods and food security of those who participate directly in these activities, supply inputs to them, or use their outputs to produce other goods or services. The productivity of farm fields, pastures, and forests will be impacted by changes in water balances, temperatures, and climatic extremes, as well as by the beneficial effects of increased carbon dioxide concentrations. Although climate change can and will have both positive and negative impacts on rural economies and livelihoods, predominantly negative effects are expected in developing countries.

The AIACC studies demonstrate that systems with similar exposures to climate stimuli can vary considerably in their vulnerability to damage from the exposures. Factors both internal and external to the household determine its vulnerability to climate change. External factors found to increase the vulnerability of rural households include a high proportion of households engaged in subsistence or small scale farming or herding on marginal lands; scarcity of water and other resources; rapidly growing population; poorly diversified income opportunities in the local economy; high poverty rates; inadequate health, education and other services; lack of social safety nets; gender inequality; declining local authority; governance failures; violent conflict; and competition from market liberalization. Internal factors are addressed by the next lesson.

A household's access to water, land, and other resources is an important determinant of its vulnerability. The sensitivity of a household's livelihood and food security to changes in climate and land productivity and its capacity to respond are shaped to a significant degree by the resources available to it. Findings from case studies of rural communities in southern Africa, the Sudano-Sahel zone, South America and Southeast and Central Asia reveal that internal characteristics of households that are determinants of their vulnerability include access to safe water and sanitation; security of water rights; land-tenure status; farm size and soil quality; number of animals owned; quantity and quality of household labor supply; ownership of farm equipment; amount and diversity of household income; financial savings; access to credit; food stores; health status of household members; and gender of household head.

Multiple factors converge to make the people inhabiting coastal zones and small islands highly vulnerable. Coasts and small islands are highly exposed to a variety of climate hazards that may be affected by global climate change. The climatic hazards converge with local and regional human pressures to create conditions of high vulnerability, particularly in areas with high concentrations of people and infrastructure along low-lying coasts. Climate factors that influence the vulnerabilities of coasts and small islands include sea-level rise; the frequency and intensity of tropical and extra-tropical storms; changes in winds, water temperatures, and freshwater inflow to estuaries and coastal waters; ENSO and monsoon variability; and water balances. Non-climate drivers include land use planning and management; flood and erosion control; health of wetlands, reefs, and other natural barriers; systems for disaster prevention, preparedness, warning, and response; dependency on tourism; and pollution.

Along the Argentine coast of the Rio de la Plata, projected changes in sea level are expected to increase the area and population affected by recurrent flooding from storm surges – hundreds of thousands of additional people are estimated to be at risk during the 21st century. Acceleration of coastal erosion due to climate change is a concern in Fiji, the Cook Islands and the Seychelles. In the Seychelles, coral bleaching has reduced the ability of reefs to dissipate wave energy, accelerating beach erosion, reef degradation, and damage to coastal infrastructure. The islands' strong dependency on tourism and the high sensitivity of their tourism attributes (e.g., beaches, hotels) to climate hazards creates conditions of high socioeconomic vulnerability to climate change.

Vulnerability to adverse health impacts is greater where health care systems are weak and programs for disease surveillance and prevention are lacking. Many vector-borne infectious diseases are climate sensitive and epidemics of these diseases can occur when their natural ecology is disturbed by environmental changes. Projected changes in rainfall and temperature have the potential to expose more people to vector-borne diseases, such as malaria in the highlands of East Africa and dengue fever in the Caribbean, by expanding the geographic range of vectors and pathogens into new areas, increasing the area of suitable habitat and the numbers of disease vectors in endemic areas, and extending the length of transmission seasons. Changes in the incidence, extent, and severity of disease epidemics depend on more than climate stresses and disease ecology, however. Demographic, social, economic and other factors also determine exposure, transmission, infection, treatment, and prognosis. Vulnerability to severe health outcomes is greatest where health care systems are degraded; where large numbers of people lack access to health care; where a population's immunity, nutrition, and general health status is low; and where effective programs for disease surveillance, vector control, and prevention are lacking. Where the converse of these conditions holds, the likelihood of severe health outcomes is much diminished.

Some ecosystems and many of their species may be lost to climate change. Climate change is already having observable impacts on ecosystems and by the end of the 21st century may become the dominant driver of ecosystem change and biodiversity loss. The vulnerability of ecosystems and species to climate change is influenced by the specificity of their climate requirements, the change in spatial extent of areas that match those requirements, the degree of connectivity between suitable areas, the rates at which suitable climates move across the landscape, and the rates at which different species can migrate. Vulnerability is also shaped by other human-caused pressures that weaken ecosystem resilience and by land uses that fragment the landscape and pose barriers to species migration.

An AIACC study of ecosystem responses to climate change in South Africa finds that the Succulent Karoo biome, an arid ecosystem rich in biodiversity and high in species endemism, could disappear almost entirely, resulting in extinction of many of the species endemic to the biome. Also vulnerable, but likely less so, is the fynbos biome, which is the major vegetation type of the highly diverse Cape Floral Kingdom. Many fynbos species are projected to be able to migrate with climate driven shifts in their habitats, but some will not and will be lost. The savannas are found to be the least vulnerable of the South African biomes studied. In the Philippines, increasing temperature and rainfall are projected to cause dry and moist forest types to disappear and be replaced by wet forests and rainforests. The transition would likely result in the loss of many dry and moist forest species.

2.4 Natural Resources

Natural resources, pressured by human uses, have undergone rapid and extensive changes over the past 50 years that have degraded many of these resources (Millennium Ecosystem Assessment (MEA), 2005). Population and economic growth are likely to intensify uses of and pressures on natural resource systems. Global climate change, which has already impacted natural resource systems across the Earth, is adding to the pressures and is expected to substantially disrupt many of these systems and the goods and services that they provide (IPCC, 2001b; IPCC, 2007; MEA, 2005). The AIACC studies investigated vulnerabilities from climate impacts to a variety of natural resources, which are grouped into the contexts water, land and ecosystems and biodiversity.

2.4.1 Water

Population and economic growth are increasing water demands and many parts of the world are expected to face increased water stress as a result (Arnell, 2004). Water resources are highly sensitive to variations in climate and consequently climate change will pose serious challenges to water users and managers (Gleick et al, 2000; IPCC, 2001b). Climate change may exacerbate the stress in some places but ameliorate it in others, depending upon the changes at regional and local scales.

Vulnerabilities from water resource impacts of climate change are addressed by several of the AIACC studies. Outcomes of concern for water resources from these studies and the climatic and non-climatic drivers of the outcomes are identified in Table 2.1. Scenarios of future climate change indicate that many of the AIACC study regions, including much of Africa and parts of Asia, face risks of greater aridity, more variable water supply, and periods of water scarcity from drought. In contrast, scenarios suggest that the climate may become wetter and water supply greater in southeastern South America and southeastern Asia.

Table 2.1: Water resource vulnerabilities

Level of Concern	Outcomes of Concern	Climate Drivers	Other Drivers	AIACC Studies
High	• Collapse of water system leading to severe and long-term water shortage	• Persistent and severe decline in water balance due to reduced rainfall and/or higher temperatures • Sea level rise causing salt-water intrusion into shallow aquifer of small island • Disappearance of glaciers	• High dependence on single vulnerable water source • Lack of alternative water sources • High and growing water demand relative to reliable supply • Failure of water and land-use policy, planning and management	
	• Water scarcity that retards progress on Millennium Development Goals and threatens food security	• Persistent, regional decrease in rainfall, increase in aridity • More variable rainfall and runoff • More frequent severe drought events	• High and growing water demand relative to reliable supply • High dependence on subsistence or small-scale rain-fed crop farming and herding • Land degradation • High poverty rate • Insufficient investment in rural development • Inequitable access to water • Lack of social safety nets Governance failures	• Sudan (Osman-Elasha and Sanjak, 2008) • Northern Nigeria (Nyong et al, 2008) • Mongolia (Batima et al, 2008) • Mexico (Eakin et al, 2008)
Medium	• Losses from reallocations of water among competing users • Non-violent but costly conflict among competing water users	• Persistent and moderate decrease in rainfall, increase in aridity • More variable rainfall and runoff • More frequent severe drought events • Changes in timing of runoff and water availability	• High and growing water demand relative to supply • Extensive land use changes • Pollution from industrial, agricultural and domestic sources • Undefined or insecure water rights • Poor performance of institutions for water planning, allocation and management	• Western China (Yin et al, 2008) • Philippines (Pulhin et al, 2008) • South Africa (Callaway et al, 2008)

	• More frequent flood events that increase loss of life, damage to infrastructure, loss of crops and disruption of economic activities	• Increase in heavy precipitation events	• Growth in populations and infrastructure in flood-prone locations • Poorly managed land-use change, including clearing of vegetation and filling of wetlands that can provide flood protection Ineffective disaster prevention, preparedness, warning and response systems	• Argentina (Eakin et al, 2008) • Argentina (Barros et al, 2008) • Thailand and Lao PDR (Chinvanno et al, 2008) • Philippines (Pulhin et al, 2008)
ow	• Losses to water users from localized, temporary and manageable fluctuations in water availability	• Seasonal droughts	More severe effects kept in check by: • Effective management, planning and policies for water demand and supply	• Philippines (Pulhin et al, 2008) • Western China (Yin et al, 2008) • Thailand and Lao PDR (Chinvanno et al, 2008) • South Africa (Callaway et al, 2008)

Changes in water balances will impact land, ecosystems, biodiversity, rural economies, food security and human health and vulnerabilities to these impacts are discussed in later sections of the paper. The outcomes are strongly dependent upon factors such as the level and rate of growth of water demands relative to reliable supplies; water and land use policies, planning and management; water infrastructure; and the distribution and security of water rights. Where water becomes less plentiful and climates drier, the changes have the potential to retard progress toward Millennium Development Goals.

The devastating impacts that can result from persistent and geographically widespread declines in water balances have been demonstrated too frequently. Osman-Elasha and Sanjak (2008) and Nyong et al (2008) examine the impacts of decades of below average rainfall and recurrent drought in two parts of the Sudano-Sahel zone with case studies in Sudan and Nigeria respectively. The reduced availability of water in these arid and semi-arid areas has resulted in decreased food production, loss of livestock, land degradation, migrations from neighboring countries, and internal displacements of people. The effects of water scarcity have contributed to food insecurity, the destitution of large numbers of people and are also implicated as a source of conflict that underlies the violence in Darfur (see Section 2.6.3).

Non-climate factors that have contributed to the severity of impacts of past climatic events in Sudan and Nigeria create conditions of high vulnerability to continued drying of the climate and future drought. Both studies find that large and growing populations in dry climates that are highly dependent on farming and grazing for livelihoods, lack of off-farm livelihood opportunities, reliance of many households on marginal, degraded lands, high poverty levels, insecure water rights, inability to economically and socially absorb displaced people, and dysfunctional governance institutions create conditions of high vulnerability to changes in water balances. While projected water balance changes for the Sahel and Sudano-Sahel zones are mixed (Hoerling et al, 2006), they include worrisome scenarios of a drier, more drought-prone climate for these regions.

The Heihe River basin of northwestern China has experienced more modest drying over the past decade (Yin et al, 2008). But with increasing development in the basin, water demands have been rising and intensifying competition for the increasingly scarce water. As a result, water users in the basin have become more vulnerable to water shortage, reduced land productivity, and non-violent conflict over water allocations. These effects illustrate outcomes of medium and low level concern. A drier climate, as some scenarios project for the region, would exacerbate these conditions and could result in outcomes of higher-level concern if future development in the basin raises water demand beyond what can be supplied reliably and sustainably.

For the case study regions in the eastern part of the southern cone of South America (Conde et al, 2008, Eakin et al, 2008, and Camilloni and Barros, 2003), the Philippines (Pulhin et al, 2008), and Lower Mekong River basin (Suppakorn et al, 2008), climate change projections suggest a wetter climate and increases in water availability. In the southern cone of South America, increased precipitation over the past two decades has contributed to the expansion of commercially profitable rain-fed crop farming, particularly of soybeans, into cattle ranching areas that were previously too dry for cropping. While this has generated significant economic benefits, the increased rainfall has also brought losses from increases in heavy rainfall and flood events. In the future, a wetter climate in these regions would also bring benefits from increased water availability, but may also cause damages from flooding, water-logging of soils (Eakin, et al 2008), and greater rainfall variability that may include both heavier rainfall events as well as more frequent droughts (IPCC, 2001a) that would add to risks faced by farmers.

In the Pantabangan-Carranglan watershed of the Philippines, increases in annual rainfall and water runoff would benefit rain-fed crop farmers, irrigators, hydropower generators, and other water users. But changes in rainfall variability, including those related to changes in ENSO variability, could intensify competition for water among upland rainfed-crop farmers, lowland irrigated-crop farmers, the National Power Corporation, and National Irrigation Administration (Pulhin, et al, 2008). Changes in flood risks are also of concern in the watershed. In the lower Mekong, while increases in annual rainfall may bring increases in average rice yields, shifts in the timing of rainy seasons and the potential for more frequent flooding are found to pose risks for rice farmers (Suppakorn, et al, 2008). Those most vulnerable to changes in variability in the lower Mekong and in Pantabangan-Carranglan appear to be small farmers with little or no land holdings, lack of secure water rights, limited access to capital and other resources, and limited access to decision-making processes.

2.4.2 Land

The quality and productivity of land is strongly influenced by climate and can be degraded by the combined effects of climate variations and human activities. Land degradation has become one of the most serious environmental problems, reducing the resilience of land to climate variability, degrading soil fertility, undermining food production, and contributing to famine (UNCCD, 2005a). Seventy percent of the world's drylands, including arid, semi-arid and dry sub-humid areas, are degraded, directly affecting more than 250 million people and placing 1 billion people at risk (UNCCD, 2005b).

Human caused climate change is likely to affect land degradation processes by altering rainfall averages, variability and extremes and by increasing evaporation and transpiration of water from soils, vegetation and surface waters. The effects on land will depend in part on how the climate and water balances change. But they will also depend strongly on non-climate factors that shape human pressures on land. The human consequences will in turn be shaped by the ability of people to cope and respond to the effects and to reduce the human pressures that drive land degradation.

Two AIACC case studies, one in Northern Darfur, Sudan (Osman-Elasha and Sanjak, 2008) and the other in Mongolia (Batima et al, 2008), have land degradation as a central focus. Land degradation is also found to be a potential outcome as well as an amplifier of climate change vulnerability in AIACC studies in the Philippines (Pulhin, et al, 2008), Tlaxcala, Mexico (Ziervogel et al, 2008), and Tamaulipas, Mexico and the Argentine Pampas (Eakin, et al, 2008).

Table 2.2 lists some of the outcomes of concern from the studies that are related to land degradation. The ranking of outcomes is based upon the spatial extent, severity of impacts, and the reversibility or irreversibility of land degradation. The climate drivers of land degradation outcomes are increases in aridity and increases in the frequency, severity and duration of droughts. Non-climate drivers include population growth and economic incentives that create pressures to intensify land uses, expand farming and grazing activities into marginal lands, and clear vegetation. Contributing to this are land tenure systems, land policies, and market failures that limit incentives for good land and water management. Widespread poverty, breakdown of local support systems and ineffective governance institutions heighten vulnerability of populations to income and livelihood losses, food insecurity, and displacement from their homes as a result of land degradation.

Table 2.2: Land vulnerabilities

Level of Concern	Outcomes of Concern	Climate Drivers	Other Drivers	AIACC Studies
High	• Widespread desertification of lands with irreversible changes to soil structure or nutrient status	• Arid, semi-arid or sub-humid climate • Persistent decrease in rainfall, increased aridity • Increase in climate variability, including more frequent extreme droughts	• Severe overuse of land, including overly intense cropping with poor soil management, poor irrigation practices, extension of cropping into marginal lands, overgrazing of rangelands, removal of vegetation and deforestation • Land tenure systems, land-use policies, market failures and globalization forces that create pressures for overuse and limit incentives for good land management • Population pressure • Breakdown of support systems • Poverty • Poor, erodable soils	• Sudan (Osman-Elasha and Sanjak, 2008) • Northern Nigeria (Nyong et al, 2008)
	• Widespread but reversible desertification of lands	• Arid, semi-arid or sub-humid climate • Increase in climate variability, including more frequent extreme droughts	• Intensive use of land that degrades land productivity during dry periods but does not irreversibly alter soils • Population pressures • Poverty • Inability of land management systems to adapt to climate variations	• Sudan (Osman-Elasha and Sanjak, 2008) • Northern Nigeria (Nyong et al, 2008) • Mexico (Eakin et al, 2008)
Medium	• Land degradation of limited geographic extent that is irreversible	• Increased aridity of limited geographic extent • Increase in climate variability, including more frequent extreme droughts	• Locally severe overuse of land • Population pressures • Poverty	• Mongolia (Batima et al, 2008) • Mexico (Eakin et al, 2008) • Philippines (Pulhin et al, 2008)
Low	• Localized but reversible land degradation	• Moderate, temporary drying of localized extent	More severe effects kept in check by: • Tenure systems and land policies that promote good land management • Households that have sufficient resources with which to cope with reduced food and fodder production • Social systems that function to absorb shocks	• Mexico (Eakin et al, 2008) • Philippines (Pulhin et al, 2008)

In northern and central states of Sudan, the dry climate, sandy soils, and heavy human pressures on the land create conditions of high vulnerability to desertification. Below average rainfall over the past 20 years and growing land use pressures have degraded grazing and crop lands in North Darfur and reduced food and fodder production and the availability of water (Osman-Elasha and Sanjak, 2008). The scarcity of these lifelines has triggered southward migrations of people and their livestock within North Darfur. In addition, persons fleeing civil war in neighboring Chad also migrated into western Sudan.

The resulting rapid increases in human population and the number of livestock have intensified pressures on the already fragile environment, including over-grazing and excessive cutting of gum arabic (Acacia senegal) trees to clear land for cultivation and provide fodder and firewood. The reduction in vegetation cover has increased vulnerability to loss of soil and soil fertility by exposing soils to wind erosion and encroachment of desert sands. Similar processes are degrading lands in Sudan's North Kordofan state (Ziervogel, et al, 2008). The human consequences of drought and land degradation in Sudan are explored below in Section 2.6.3. If, as some climate projections suggest, the future climate of the region becomes drier and the frequency and severity of droughts increase, desertification processes would be exacerbated.

Mongolia, a nation for which livestock herding is the dominant livelihood activity, is also experiencing serious land degradation (Batima et al, 2008). Over the past 40 years, pasture production has declined 20-30 percent. Rainfall has stayed relatively constant over this period, increasing slightly in some areas and decreasing in others. However, increases in mean temperatures ranging from near 1°C in the low mountains and on the plains of the Gobi desert to more than 2° C in the high mountains have resulted in drying of the climate and soils and reduced forage production. Overstocking and overgrazing of pastures in the drier conditions has lead to degradation of lands in parts of Mongolia. Reduced fodder production on the degraded lands has caused reductions in the numbers and weights of animals that can be raised by herders. Drought years, combined with severe winters, have had devastating impacts on animal herds and herders (see Section 2.6.2 below). Climate projections indicate that temperatures will continue to rise and suggest that the region may become drier. Such scenarios would worsen problems of land degradation in Mongolia.

2.4.3 Ecosystems and Biodiversity

Habitat change, overexploitation, invasive alien species, pollution and climate change are identified by the Millennium Ecosystem Assessment as the most important drivers presently of ecosystem change and biodiversity loss. By the end of the 21st century, it is possible that climate change may become the dominant driver (MEA, 2005). AIACC case studies in South Africa (von Maltitz and Scholes, 2008) and the Philippines (Lasco et al, 2008) investigate the potential changes in the spatial extent of ecosystem types and biodiversity loss for scenarios of climate change. The findings of these studies are summarized here. Other AIACC studies examine the impacts of climate change on the productivity of ecosystems and are discussed in sections of this paper on water, land, coastal systems, and rural economy.

Outcomes of high, medium and low levels of concern from the South African and Philippine studies are presented in Table 2.3. At the high end of the scale, the two studies find that loss of some entire ecosystems, along with many of their species, is probable for changes in climate that are projected for a doubling of atmospheric concentration of carbon dioxide.

Table 2.3: Ecosystems and biodiversity vulnerabilities

Level of Concern	Outcomes of Concern	Climate Drivers	Other Drivers	AIACC Studies
High	• Collapse or loss of entire ecosystem and extinction of many of the system's species	• Rapid rate of change in mean temperature • Changes in water balance across an ecosystem's geographic distribution that are beyond tolerance limits of dominant species • Changes in seasonal climate extremes, variability and means	• Narrow climate tolerances of dominant species of an ecosystem • Extensive habitat loss and fragmentation due to land-use change • Severe pressure from overgrazing, over-harvesting, over-fishing, etc • Severe competition from invasive species • Severe pressure from pollution • Changing fire regimes • Physical barriers to species migration (e.g. islands, mountain tops, isolated valleys) • Changes in grass–tree interactions due to increase CO_2 in atmosphere	• South Africa (von Maltitz and Scholes, 2008) • Philippines (Lasco et al, 2008)

<table>
<tr><td rowspan="2">Medium</td><td>• Species loss and retrogressive succession</td><td>• Greater water stress from higher temperatures and lower precipitation</td><td>• Moderate pressure on ecosystems due to habitat loss and fragmentation, overexploitation, competition from invasive species, and pollution
• Changing fire regimes
• Changes in grass–tree interactions due to increase CO_2 in atmosphere</td><td>• South Africa (von Maltitz and Scholes, 2008)</td></tr>
<tr><td>• Species loss and change in habitat compositional structure</td><td>• Slow changes in climate that allow most species to migrate</td><td>• Sufficient connections of suitable habitat persist across the landscape to enable species to migrate</td><td>• South Africa (von Maltitz and Scholes, 2008)</td></tr>
<tr><td>Low</td><td>• Genetic loss
• Loss of genetic variability, loss of sub-species and varieties</td><td>• Slow changes in climate
• Small absolute changes in temperature and precipitation that do not fundamentally alter water balances</td><td>More severe effects kept in check by:
• Managing pressures on ecosystems to a low level
• Connections of suitable habitat enable species to migrate</td><td>• South Africa (von Maltitz and Scholes, 2008)</td></tr>
</table>

The vulnerability of ecosystems and species to adverse outcomes from climate change is determined in part by how specialized or general are their climate requirements, changes in the spatial extent and connectivity of areas with climates that match these requirements, the rate at which areas with suitable climates move across the landscape in response to climate change, and the potential rates at which species and communities of species can migrate. Vulnerability is also determined by human caused pressures on ecosystems in addition to climate change that may weaken their resilience, by human-made obstacles that can impede species migration, and by human efforts to relieve pressures and make obstacles more porous.

In the South African example, projected increases in aridity in the western half of the country would cause current biomes to contract and move toward the eastern half of the country. A large proportion of South Africa would be left with a habitat type that is not currently found in the country. The impacts vary by location and biome type and for individual species.

The savanna systems of South Africa and their species are found to have relatively low vulnerability to climatically driven extinctions. In comparison, species of the fynbos biome are potentially more vulnerable to climate change than are those of the savannas. The fynbos is the major vegetation type of the Cape Floral Kingdom, which is the smallest of the world's 6 floral kingdoms. It is located entirely in South Africa, has the highest concentration of species of any of the floral kingdoms, and has a species endemism rate of 70 percent. While the fynbos biome is projected to have relatively little loss in spatial extent, climatic habitats would move for many individual species and some climatic habitats would disappear completely. Model simulations suggest that many species of the fynbos will be able to migrate with their moving habitats, but some would not and would be lost.

The situation for the Succulent Karoo biome, an arid ecosystem of southwestern South Africa and southern Namibia that is also rich in biodiversity and high in species endemism, is more dire. Model simulations for climate change scenarios corresponding to a doubling of carbon dioxide project that almost the entire extent of the Succulent Karoo would be lost to a new climatically defined habitat type. Extinction of many of the species endemic to the biome would likely result.

In the Philippines, increasing temperature and rainfall are projected to result in the dry forest zone being completely replaced by wet forests and rainforests (Lasco et al, 2008). They estimate that a 50 percent increase in precipitation would cause dry forests, which occupy approximately 1 million hectares, to disappear completely from the Philippines and moist forests, which occupy 3.5 million hectares, to decline in area by two-thirds. Most of these forest areas would become wet forests, which would more than double from their present size. If precipitation were to increase by 150 percent, which is within the range of GCM scenario projections for the end of the century, all dry and moist forests would disappear, wet forests would decline by half, and rain forests, a forest type not currently present in the Philippines, would increase to 5 million hectares. The warmer, wetter climate that is projected for the Philippines would increase the primary productivity of the forests and produce associated benefits, but the disappearance of dry and possibly moist forest types would result in losses of species.

2.5 Coastal Areas and Small Islands

Coasts and small islands are highly exposed to a variety of climate hazards that may be affected by global climate change. The climatic hazards converge with local and regional human pressures in coastal zones to create conditions of high vulnerability, particularly in areas with high concentrations of people and infrastructure along low-lying coasts. Barros et al (2008) investigate flood risks from storm surges along the Argentine coast of the Rio de la Plata. Nagy et al (2008), also working in the Rio de la Plata basin, examine changing dynamics of the estuarine ecosystem and their implications for fisheries on the Uruguayan side. Payet (2008) explore problems of coastal erosion and also risks to tourism in the Seychelles, while Mataki et al (2005) assess the vulnerability of coastal towns of Fiji to flooding. Outcomes of concern from these studies are summarized in Table 2.4.

Table 2.4: Coastal area and small island vulnerabilities

Level of Concern	Outcomes of Concern	Climate Drivers	Other Drivers	AIACC Studies
High	• More frequent and greater loss of life, infrastructure damage, displacement of population and disruption of economic activities	• Increase in frequency and intensity of extra-tropical and tropical storms • Sea level rise	• Large and growing population and infrastructure in exposed coastal areas • Lack of land-use policies to avoid/reduce exposures • Lack of maintenance of flood control infrastructure • Loss of wetlands and reefs • Ineffective disaster prevention, preparedness, warning and response systems	• Central America (Project LA06, www.aiaccproject.org) • Argentina (Barros et al, 2008)
	• Loss of tourism-related income, export earnings and jobs	• Changes in number of wet days and frequency of storms	• Damages to infrastructure, beaches, water supply and ecosystems that provide tourism-related services • High dependence on tourism for income and employment	• Seychelles (Payet, 2008)
	• Severe coastal erosion	• Increase in frequency and intensity of extra-tropical and tropical storms • Sea level rise	• Intensive land uses in the coastal zone • Loss of coastal wetlands and bleaching of coral reefs	• Seychelles (Sheppard et al, 2005; Payet, 2008) • Fiji (Mataki et al, 2005 and 2006)
Medium	• Damage to coastal ecosystems and their services and resulting impacts on fishing livelihoods	• Sea level rise • Changes in winds, water temperatures, and freshwater inflow to estuaries and coastal waters	• Pollution discharges into waters • Nutrients carried into coastal waters by runoff • Use of fertilizers that runoff into coastal waters • Removal of vegetation that increases erosion • Hardening of shoreline to protect against storm surges • Over-harvesting of fish and shellfish	• Uruguay (Nagy et al, 2008)

	• Diminishing and less reliable water supply	• Sea level rise • Changes in water balance and ENSO and monsoon variability	• Increasing water demand from growing population and economic activity • Increasing extraction of groundwater	• Fiji (Mataki et al, 2005 and 2006)
Low	• Modest acceleration of coastal erosion and modest infrastructure damage	• Increase in frequency and intensity of extra-tropical and tropical storms • Sea level rise	More severe effects kept in check by: • Low concentrations of population and infrastructure in areas exposed to erosion • Intact coastal wetlands and inland vegetation • Good coastal policies and management practices	• Argentina (Barros et al, 2008)

Barros et al (2008) find that sea level rise would permanently inundate only small and relatively unimportant areas along the southern coast of the Rio de la Plata during this century. However, the area and population that would be affected by recurrent flooding from storm surges would increase considerably. They estimate that by 2070, sea level rise and changes in wind fields would increase the population affected by storm surges with a five-year return period from 80,000 persons at present to nearly 350,000. For storm surges with a 100 year return period, the population affected would rise from 550,000 at present to nearly 900,000 by 2070. Economic costs resulting from real estate damage and increased operational costs of coastal public facilities are estimated to range between 5 to 15 billion US dollars for the period 2050-2100, depending on the rate of sea level rise. These estimates are based on the current population and development of the basin. Continuation of trends that have been concentrating both people and infrastructure on the coast would increase the number of people exposed and the potential economic damage.

Coastal erosion is common to all coasts, but the level of concern that it engenders ranges from low to high depending upon local circumstances. Barros et al (2008) find that coastal erosion is presently of little concern in the Rio de la Plata basin, though concern could rise if newly accreted lands in the Parana delta are allowed to be settled and developed. In contrast, concern about coastal erosion is high in the Seychelles (Payet, 2008) and in Fiji and the Cook Islands (Mataki et al, 2005), where infrastructure and resources are more exposed to the impacts of erosion. A recent study in the Seychelles found that coastal erosion is significantly heightened as a result of coral bleaching events that reduce the ability of reefs to dissipate wave energy (Sheppard et al, 2005). They conclude that areas that have experienced mass bleaching are at a higher risk from coastal erosion under accelerated sea-level rise.

In the Seychelles, as in many island states, tourism is a major contributor to incomes. The attributes that make the Seychelles and other islands attractive tourist destinations can be highly sensitive to climate stresses. The high economic dependence on tourism and the sensitivity of tourist resources to climate create a situation of high socioeconomic vulnerability to climate change (Payet, 2008). Climate change can impact tourism by accelerating beach erosion, inundating and degrading coral reefs, damaging hotels and other tourism related infrastructure, and discouraging tourists from visiting because changes in climate reduce its appeal.

While local actions can help to relieve problems of beach erosion, stresses on corals and coastal wetlands, and infrastructure damage, the latter risk is not easily mitigated. In a scenario that assumes a substantial increase in the number of wet days per month, Payet estimates that tourist visits would be reduced 40 percent. They also estimate that the decrease in tourist visits would reduce tourism expenditures by 40 million USD and cause over 5000 jobs to be lost, or 15 percent of the national labor force. The effects would be felt in all areas of the economy.

The trophic state of the estuary of the Rio de la Plata has degraded since the mid-1940s. The eutrophication of the estuary is due primarily to nutrients introduced by increased fertilizer use and changes in human land uses, but climatic factors such as changes in river flows and wind patterns have also contributed (Nagy et al, 2008). A consequence of the eutrophication is an increase in the frequency of harmful algae blooms in the last decade, resulting in considerable economic harm to commercial fisheries and tourism as well as negative impacts on public health in Uruguay. Climate change would impact the estuary through changes in freshwater input from tributaries and changes in winds that would modify the circulation, salinity front location, stratification and mixing patterns. These changes would in turn alter oxygen content, nutrients, and primary production in the estuary.

Many of the estuary's services would be altered. But the specific changes are difficult to predict as they depend upon the balance of multiple and complex interactions. One of the concerns is the sustainability of fisheries in the Rio de la Plata. A case study of an artisanal fishery located on the northern coast of the Rio de la Plata finds the fishermen and the fishing settlement to be vulnerable to climate driven shifts in the salinity front location and other changes in the estuary that would alter fish catch or the effort and cost to catch fish.

2.6 Rural Economy and Food Security

Rural economies, which are based upon and dominated by agricultural, pastoral and forest production, are highly sensitive to climate variations and change. So too are the livelihoods and food security of those who participate directly in these activities, supply inputs to them, or use their outputs to produce other goods and services.

Several AIACC case studies investigate the potential impacts of climate variability and climate change on production processes of rural economies and the vulnerability of households' livelihoods and food security to the impacts. Climate change can and will have both positive and negative impacts on rural economies and livelihoods. Table 2.5 highlights some of the potential negative outcomes identified as concerns by the studies. The focus is on negative outcomes because our interest is in understanding who is vulnerable in rural economies, how they are vulnerable and why. This focus is appropriate as previous studies find that predominantly negative effects can be expected for agriculture in developing countries (IPCC, 2001b).

Table 2.5: Rural economy vulnerabilities

Level of Concern	Outcomes of Concern	Climate Drivers	Other Drivers	AIACC Studies
High	• Violent conflict • Famine	• Persistent below average rainfall, increased aridity • Severe, multi-year, geographically widespread drought events	• Tensions among rival groups • Migrations of herders into lands of sedentary farmers • Collapse of local authorities • Governance failures • Scarcity of food, water and other resources	• Sudan (Osman-Elasha and Sanjak, 2008) • Northern Nigeria (Nyong et al, 2008)
	• Multi-year collapse of rural production systems • Widespread and persistent loss of livelihoods and impoverishment • Chronic hunger and malnutrition for large percentage of population • Long-term or permanent out-migration on large scale	• Persistent below average rainfall, increased aridity • Severe, multi-year, geographically widespread drought events	• Large and growing population in dryland areas • High percentage of households engaged in subsistence or small-scale farming and herding on lands with poor soils and no irrigation • Overuse or clearing of lands leading to land degradation • Lack of or insecure water rights • High poverty rate • Lack of off-farm livelihood opportunities • Lack of social safety nets • Governance failures	• Sudan (Osman-Elasha and Sanjak, 2008) • Northern Nigeria (Nyong et al, 2008) • Mongolia (Batima et al, 2008)

Medium	• Loss of export earnings • Loss of national income • Loss of jobs	• More frequent climate extremes over large portion of growing area of key export crops • Changes in average climate or shifts in rainy season that stress export crops	• High dependence on small number of agricultural commodities for export earnings, national income and employment • Declining or volatile export crop prices • Insufficient investment in research, development and diffusion of agricultural technology	• Sri Lanka (Ratnasiri et al, 2008)
	• Increased rural poverty rates • Declining and more variable net farm incomes for many rural households • Failures of small farms • Accelerated rural-to-urban migration	• Region-wide increase in frequency of climate extremes that cause losses of crops, livestock and income • Changes in average climate or significant shifts in rainy season that stress traditionally grown crops and available substitutes	• Declining output prices (e.g. due to trade liberalization) • Rising input prices (e.g. due to removal of subsidies) • Lack of income diversification of rural households • Lack of access to credit by small farmers • Stagnant rural development • Poor rural infrastructure (e.g. roads, water storage) • Lack of social safety nets	• Argentina and Mexico (Eakin et al, 2008) • South Africa, Nigeria, Sudan and Mexico (Ziervogel et al, 2008) • Thailand and Lao PDR (Chinvanno et al, 2008) • Philippines (Pulhin et al, 2008)
Low	• Declining and more variable net farm incomes for some rural households • Decreased and more variable quality of crop and livestock output • Temporary migrations as strategy to obtain off-farm incomes	• Increase in frequency of climate extremes that cause losses of crops, livestock and income • Changes in average climate or shifts in rainy season that are less optimal for traditionally grown crops	More severe effects kept in check by: • Robust and diversified rural development • Equitable access to resources (e.g. improved seed varieties) • Adequate household savings • Maintenance of social safety nets • Political stability • Well maintained rural infrastructure and services • Access to credit and insurance	• Argentina and Mexico (Eakin et al, 2008) • Thailand and Lao PDR (Chinvanno et al, 2008) • Philippines (Pulhin et al, 2008) • Sri Lanka (Ratnasiri et al, 2008)

Changes in the productivity of farm fields, pastures and forests will be influenced by changes in water balances, changes in temperature averages and ranges, changes in the frequencies and severities of droughts, floods and other climate extremes, and the ameliorating effects of higher carbon dioxide concentrations on plant processes. One of the common findings of the studies is that systems with similar exposures to climate stimuli can vary considerably in their vulnerability to damage from the exposures.

The particular factors that determine vulnerability are context specific and vary from place to place. But some commonalities can be identified. Rural households' sensitivity to climate shocks and capacity to respond vary according to their access to water, land and other resources. Large and growing populations, high proportion of households engaged in subsistence or small scale farming and herding, land degradation, high poverty rates, and governance failures create conditions of vulnerability for rural economies and households. Declining local authority, lack of social safety nets, violent conflict, gender inequality and competition from market liberalization are also factors that add to vulnerability in the different case study areas. These issues are developed in the sections below.

2.6.1 Household access to resources

Access or entitlements to land, water, labor and other inputs to rural production processes are important determinants of the vulnerability of rural households. They shape the sensitivity of households' livelihoods and food security to variations in climate and land productivity. They also underpin the capacity of households to withstand and respond to the impacts.

Ziervogel et al (2008) compare the determinants of food insecurity from four case studies: Mangondi village in Limpopo Province, South Africa, Gireigikh rural council in North Kordofan, Sudan, Chingowa village in Borno State, Nigeria, and Tlaxcala State, Mexico. Each of the study sites is in a dry, drought prone climate and exposure to declining precipitation and drought are a source of risk to household food security. They find that household characteristics related to resource access play a dominant role in determining household vulnerability. These include household income, income diversification, area of land cultivated, soil quality, household labor per hectare cultivated, and health status of household members. Factors external to the household also control access to resources needed to cope with and recover from climate shocks. These include existence of formal and informal social networks, availability and quality of health services, and prices of farm inputs and outputs. In each of the case studies, labor available to the farm household is adversely affected by rural-urban migration and infectious disease such as HIV/AIDS and malaria.

Adejuwon (2008) compares the vulnerability of peasant households to climate shocks in different states of Nigeria using household census data. He finds that the percentage of households employed in agriculture, poverty rate, dependency ratio, access to potable water, health status, and educational attainment are important determinants of vulnerability. Also important is the aridity of the climate and quality of soils. The comparison identifies households in the northern states of Nigeria as the most vulnerable in the country. Nyong et al (2008) conduct detailed surveys of households of this region to identify household characteristics that control vulnerability. Key characteristics include ownership of land and livestock, area and quality of land cultivated, sufficiency of annual harvest relative to household food needs, dependency ratio, cash income, livelihood diversification, gender of household head and connections to family and social networks. Women in this patrilineal society can be particularly vulnerable.

In the Pantabangan-Caranglan watershed of the northern Philippines, households are exposed to variability in rainfall and water supply as well as to flood events (Pulhin et al, 2008). The vulnerability of households to these exposures is found to be correlated with variables that determine access to and control of resources: ownership of land, farm size, farm income, gender, and status as a native or migrant to the basin. Larger land owners, identified by community members as "rich farmers," are less vulnerable to variable incomes and other impacts of climate events than are small-holder farmers due to their greater resources for coping and recovery, their ability to live in locations that are less exposed to flooding and erosion, and their ability to capture more of the benefits from development projects due to their ties to the institutions that implement these projects. Projections of future climate change suggest the potential for greater precipitation in the Philippines, which would ease water scarcity in most years. However, flooding would become a more frequent stress and would likely impact poor, small-holder farmers of the basin the hardest.

Chinvanno et al (2008) similarly find that land ownership and other indicators of economic vitality are important determinants of the vulnerability of rice farmers in the Lower Mekong basin. Farmers of rain-fed rice in Thailand and Lao People's Democratic Republic (PDR) are exposed to variations in rice harvests and other impacts from seasonal flooding, shifts in the dates of onset and cessation of the rainy season, and variations in rainfall amounts. Farm households with small land holdings produce low volumes of rice and incomes from rice, which are often only enough to sustain the household on a year-to-year basis. As a result, smallholder farm households have very limited buffering capacity to deal with losses or to cope with anomaly during the crop season. Small land holdings also limit the ability of the farmer to implement other activities to diversify their income sources. Comparing farm households from the Thai study sites with those at the Lao PDR site, Chinvanno et al (2008) find that a larger portion of the Thai farmers are at high risk from climate shocks due to higher food costs relative to farm income, lack of income diversification, little savings in the form of financial assets, livestock or food stores, and high debt relative to income.

2.6.2 Land degradation

Land degradation is both an outcome of climate stress and a source of additional stress that can amplify the vulnerability to climate impacts of people making a living from the land. It is found to be an important factor in several AIACC case study areas, including Mongolia (Batima et al, 2008), Sudan (Osman-Elasha and Sanjak, 2008), Nigeria (Nyong et al, 2008), the Philippines (Pulhin et al, 2008), Argentina and Mexico (Eakin et al, 2008).

In the grazing lands of Mongolia, land degradation has been severe due to a harsh and variable climate, drying of the climate over a 40 year period, and heavy grazing pressures. As noted in Section 2.4.2, these conditions have depressed pasture productivity and livestock production. Batima et al (2008) find that these stresses have created a high level of vulnerability among herders to climate extremes, as was demonstrated by events in 1999 – 2003. Several years of summer droughts and severe winter conditions (called *zud*) combined to drastically reduce pasture production, animal weights at the start of winters, and stores of fodder for winter months. Approximately 12 million head of livestock died as a result, roughly one-quarter of Mongolia's herds. Thousands of families lost animals, an important source of savings, which increased poverty and reduced further the capacity of livestock dependant households to cope with shocks. Many lost their livelihoods with their animals and migrated to towns and urban centers where unemployment is high and few opportunities awaited them. Climate scenarios suggest the potential for further drying of the climate and Mongolia's herders continue to be in a state of high vulnerability to the effects of land degradation, drought and *zud*.

In the Philippines' Pantabangan-Caranglan watershed, reforestation and community development projects were implemented to reverse land degradation problems and provide other benefits. However, the projects developed a dependency on the projects for livelihoods and after termination many of the jobs associated with the projects also ended. Affected households have resorted to charcoal making and kaingin (slash and burn) farming, which are damaging the fragile environment of the watershed, including the reforested areas, and increasing vulnerability to flooding (Pulhin et al, 2008).

Food insecurity is increasing in Tlaxcala, Mexico for a variety of causes, including a shortage of farm labor due to out-migration of young males, declining maize prices, and severe soil erosion problems (Ziervogel et al, 2008). The shortage of farm labor constrains the practice of soil conservation practices, which are labor intensive, and leads to the expansion of mono-cropping of maize, a system that increases soil erosion. In Tamaulipas, Mexico, mono-cropping of sorghum, which is resilient to water stress, was promoted by the national government as a strategy for managing drought risks. However, farming of sorghum under persistent drought conditions in the 1990s may have resulted in degradation of soils that is adding to farmers' risks from drought (Eakin et al, 2008). Now the government is using incentive payments to farmers to encourage them to switch to other alternatives. In the Argentine Pampas, the dramatic expansion of soybean mono-cropping is also observed to be associated with land degradation (Eakin et al, 2008). This contributes to flood problems and raises concern about the long-term sustainability of soybean farming in the region. In each of these cases, land degradation is adding to the vulnerability of farmers to climate change.

2.6.3 Conflict

Persistent low rainfall, recurrent drought, land degradation, high population growth, governance failures and other factors have deepened poverty and resulted in food and resource scarcity in the Sahel. The scarcities have contributed to tensions between competing groups and tribes. Cereal production in the region grew at a meager 1 percent annual rate over the past decade, while the population grew at an estimated 2.7 percent rate (Nyong, et al, 2008). Against this backdrop of generally tightening food scarcity, climate and other events have created conditions of crisis. Responses can and have inflamed tensions that contribute to violent conflict, compounding the vulnerability of populations to climatic and other stresses.

Events in Sudan's Northern Darfur State illustrate a case of extremely high vulnerability of the population to loss of livelihoods, livestock, lands, and personal security leading to destitution, hunger, famine and violent death (Sanjak, et al, 2008). The drivers of this human misery are multiple. Among them are twenty years of below average rainfall that has severely reduced the availability of water, food and fodder in this dryland region of infertile soils. The drying climate and human pressures on the land, exacerbated by migrations of people and their livestock into the area, are degrading the land. Traditional land management systems and practices have been disrupted and bring nomadic and sedentary tribes into more frequent contact and conflict over land and other scarce resources. These resource conflicts are a major factor contributing to the widespread violence that has taken tens of thousands of lives in Darfur and forced many more to flee their homes. The lack of physical security and access to resources have devastated livelihoods, eroded capacities to cope with climate and other stresses, and threaten people of the region with famine.

Farmers and herders of northern Nigeria face similar pressures as do those of North Darfur. In their case study of northern Nigeria, Nyong et al (2008) find that food scarcity and rising food prices have lead to intensification of farming and grazing and expansion of these activities into more marginal lands. The greater land use pressures, combined with the persistent decline in average rainfall, have added to land degradation problems. The productivity of grazing lands has declined in the north. In response, herders have migrated southward into lands of sedentary farmers, as happened in Darfur. The resulting conflicts have led to the loss of lives, the destruction of crops, livestock and farmlands, and food insecurity for those affected.

2.6.4 Commodity export oriented economies

The sensitivity of cash crop yields to climate variability and change is of considerable importance to countries that depend heavily on the contribution of cash crops to national income and foreign exchange earnings. In Sri Lanka, coconut and tea production are the largest sources of export earnings, major contributors to national income, and significant employers of labor. Ratnasiri et al (2008) investigate the effects of past climate variations on the coconut and tea sectors of Sri Lanka and develop crop models to simulate yield responses to future climate change. Below normal rainfall in coconut growing areas, historically occurring once every 2 to 4 years, has reduced coconut yields by 10 – 25 percent relative to the 30-year average. Since priority is given for domestic consumption, this results in a greater 30 – 60 percent decline of nuts available for exports, causing a significant reduction in foreign exchange earnings and national income. In the tea sector, the 1992 drought in Sri Lanka caused a 25 percent decline in tea production and a corresponding 22 percent decline in foreign exchange earnings from tea.

Projections of future climate change include scenarios of both increased and decreased average precipitation for Sri Lanka. Changes in average coconut production would follow the precipitation changes. But tea yields are sensitive to temperatures and the effects vary by location. In the lowlands, where temperatures are near the optimum for tea yields, warming would decrease yields. In the cooler uplands, tea yields would increase with warming. Hence, it is the lowland plantations, owned largely by small holders with low adaptation capacity, that are vulnerable compared to upland plantations, which are owned by large companies. But an important factor for vulnerability of these cash crop sectors will be the effect of climate change on climate variability, particularly the frequency of drought, which, as shown by past events, are a significant source of risk for these sectors.

2.6.5 Market forces and social safety nets

The case studies by Eakin et al (2008) of crop and livestock farms in Cordoba, Argentina and Tamaulipas, Mexico demonstrate the influences of international market integration and government social programs on the vulnerability of farmers. Both countries have pursued policies of trade liberalization, privatization and deregulation. The policies have opened access to international markets and foreign investments allowing, for example, the profitable expansion of soybean farming in Argentina. But competition from overseas producers and removal of price supports and input subsidies, have created a “price squeeze” for farmers, particularly for maize farmers in Mexico.

In this highly competitive environment, farm households have less margin for absorbing shocks, including crop and livestock losses from climate extremes, and so are more vulnerable. The pressures are leading to greater concentration of farms into larger scale commercial operations as smaller family farms face a number of disadvantages, including higher cost of credit, lack of access to technical skills, high dependence on crop income, greater problems with pests, and lack of scale economies. The problems for small farmers are compounded by cutbacks in state-supported social security mechanisms, resulting in declining rural incomes and increasing inequality between small and large landholders. In Tamaulipas, small farm owners and ejidatarios (communal farmers) are responding to declining and uncertain farm incomes by diversifying into off-farm sources of income, a trend that is reducing their vulnerability to direct climate impacts.

2.7 Human Health

The paths by which climate can affect human health are diverse and involve both direct and indirect mechanisms. The most direct mechanisms operate through human exposures to climatic extremes that can result in injury, illness and death. Climate and climate change also affect human health by influencing human exposure to infectious disease through effects on the biology, habitats and behaviors of disease pathogens, hosts and vectors. Even less directly, climate and climate change can affect human health through impacts on the resources that individuals and communities need to maintain good health. Direct health outcomes of concern highlighted in the synthesis workshop are summarized in Table 2.6 and are described below. Indirect health effects are briefly summarized in Section 2.7.2.

Table 2.6: Human health vulnerabilities

Level of Concern	Outcomes of Concern	Climate Drivers	Other Drivers	AIACC Studies
High	• More frequent geographically widespread and sustained epidemics of infectious and waterborne disease with high human mortality	• Geographically widespread changes in climate that increase the geographic area and number of disease vectors • More frequent heavy rainfall and drought events that disrupt water supply and sanitation and expose people to waterborne pathogens	• Severely degraded or collapsed healthcare system • Poor and declining immunity, nutritional and health status of large portion of population • High poverty rates that limit access to healthcare • Poor or non-existent programmes for disease surveillance, vector control and disease prevention • Large portion of population lack reliable access to potable water and sanitation • Land-use changes that increase habitat for disease vectors and reservoirs for zoonotic diseases	• East Africa (Wandiga et al, 2008) • Caribbean (Heslop-Thomas et al, 2008)
Medium	• Emergence of new or more virulent strains of infectious disease and more efficient disease vectors • More frequent but geographically and temporally limited epidemics with high or moderate mortality • Increase in number of infectious disease cases and mortality in endemic areas and seasons	• Changes in climate that alter disease and vector ecology and transmission pathways • Changes in climate that moderately increase exposures by expanding endemic areas and seasons	• Land-use changes that increase habitat for disease vectors and reservoirs for zoonotic diseases • Crowding • Drug resistance • International migration, travel and trade • Water storage and sanitation practices • Poor programmes for disease surveillance, vector control and disease prevention • Declining quality and increasing cost of healthcare	• East Africa (Wandiga et al, 2008) • Caribbean (Heslop-Thomas et al, 2008)
Low	• More frequent but geographically and temporally limited epidemics with no mortality • Increase in number of isolated infectious disease cases that are not life-threatening	• Changes in climate that alter disease and vector ecology and transmission pathways • Changes in climate that moderately increase exposures by expanding endemic areas and seasons	More severe effects kept in check by: • Access to healthcare • Effective disease surveillance, vector control and disease prevention • Good nutritional and health status of population • Access to potable water and sanitation	• East Africa (Wandiga et al, 2008) • Caribbean (Heslop-Thomas et al, 2008)

2.7.1 Direct Health Effects

Many vector borne infectious diseases are climate sensitive and epidemics of these diseases can occur when their natural ecology is disturbed by environmental changes, including changes in climate (McMichael, et al, 2001). For example, observations of numbers of malaria and dengue cases vary with interannual variations in climate (Wandiga et al, 2008; Heslop-Thomas et al, 2008; Kilian et al, 1999; and Lindblade, et al, 1999). In the Lake Victoria region of East Africa, significant anomalies in temperature and rainfall were recorded during the El Niño period of 1997 – 1998 and these were followed by severe malaria outbreaks. A similar association of dengue fever occurrences with ENSO variability is observed in Jamaica. Other infectious diseases that are observed to be sensitive to climate variability and change include other insect-borne diseases such as encephalitis, yellow fever, and Leishmaniasis, and water-borne diseases such as cholera, typhoid, and diarrhea (Aron and Patz, 2001; McMichael et al, 2001).

Projected changes in rainfall and temperature have the potential to expose more people to vector-borne diseases by expanding the geographic range of vectors and pathogens into new areas, increasing the area of suitable habitats and numbers of disease vectors in already endemic areas, and extending transmission seasons. For example, average temperature and precipitation in the East African highlands are projected to rise above the minimum temperature and precipitation thresholds for malaria transmission and extend malaria into areas from which it has been largely absent in the past (Githeko et al, 2000; Wandiga et al, 2008). Other studies suggest that, if El Niño events continue to increase in frequency, the elevated temperatures and precipitation would increase malaria transmission (Kilian at al. 1999; Lindblade et al 1999). In rural communities of the highlands studied by Wandiga et al (2008), risks for developing malaria and complications from the disease are amplified by low utilization of hospitals and clinics because of distance, cost and low incomes. In consequence, self-medication has become widespread. But people often do not comply with the recommended drug regimens and the drugs most commonly used in self-medication are ones for which malaria parasites have high resistance.

The health outcome identified by workshop participants as the highest level concern is sustained or oft repeated, geographically widespread epidemics with high mortality rates. At medium and low levels of concern are more frequent epidemics or outbreaks of infectious disease that may be associated with mortality but which are geographically and temporally limited. Another concern is that changes in climate may allow more virulent strains of disease or more efficient vectors to emerge or be introduced to new areas. The movement of new disease strains into new countries is exemplified by the recent appearance of dengue hemorrhagic fever in the Caribbean, a more life threatening strain of dengue fever that is thought to result from simultaneous infection by the four strains of dengue viruses. However, climate likely played little if any role in the emergence of this disease in the Caribbean (Heslop-Thomas, et al, 2008).

Whether changes in climate result in greater infectious disease incidence or epidemics, and the geographic extent and severity of epidemics that might result, depend upon complex interactions that include not just the effect of climate stresses on the ecology of infectious disease, but also on demographic, social, economic and other factors that determine exposures, transmission, results of infection, treatment and prognosis. Vulnerability to severe health outcomes are greatest where the health care system is severely degraded, large numbers of people lack access to health care, the immunity, nutritional and health status of the population is low, and effective programs for disease surveillance, vector control and disease prevention are lacking (see Table 2.6). Where the converse of these conditions hold, the likelihood that the most severe health outcomes would be realized is much diminished.

2.7.2 Indirect Health Effects

Many of the climate change impacts described in previous sections of the paper can also have health impacts by reducing individuals' resilience to disease, the resources available to them to maintain and protect their health and obtain access to health care, and the ability of their community to deliver quality health care services. Examples of these indirect effects include households placed at greater risk of illness as a result of loss of livelihood, assets and support networks from severe and persistent drought, health risks associated with displacement and crowding of population that migrates in response to climate impacts, health care systems being overburdened by increases in case loads as a result of direct health effects of climate change, and impacts of climate extremes on health care infrastructure and personnel. The severity of the indirect health outcomes that are realized will depend upon the geographic extent, persistence and return period of the triggering climatic event, the severity of impact on resource productivity, livelihoods and health care infrastructure, and the resilience of the affected area as indicated by the diversity of economic opportunities, poverty rate, health status, and capacity of the health care system relative to the population.

2.8 Conclusion

In all of the case studies, climate hazards are a significant danger now, not just in the distant future. Potential outcomes from exposure to climate hazards and climate change identified as high-level concerns include water scarcity that retards progress towards development goals, land degradation, losses of entire ecosystems and their species, more frequent and greater loss of life in coastal zones, food insecurity and famine, loss of livelihoods, and increases in infectious disease epidemics. All of these are plausible outcomes of exposures to climate hazards. Whether they are likely outcomes will vary and will depend on the degree and nature of vulnerability of the exposed systems.

Vulnerability to impacts from climate variation and change is shown by our case studies to have multiple causes. The causes include not only exposure to the climatic stressors, but also to stressors that derive from interactions among environmental, demographic, social, economic, institutional, political, cultural and technological processes. The state and dynamics of these processes differ from place to place and generate conditions of sensitivity, adaptive capacity and vulnerability that differ in character and degree. Consequently, populations that are exposed to similar climatic phenomenon are not necessarily impacted the same.

Differences in vulnerability are also apparent for different sub-populations or groups inhabiting a region, and even from household to household within a group. Factors such as sources and diversity of a household's livelihood, experience and skills, level of wealth, ownership and access to land, water and other resources, support from social networks, and access to technical assistance and knowledge give rise to differences in vulnerability between households.

Our synthesis focuses on four domains of vulnerability: natural resources; coasts and small islands; rural economies and food security; and human health. A common finding across the domains of vulnerability is that impacts ranked as high-level concerns generally are not likely to result from climate stress alone. They are most likely to be realized when multiple stresses act synergistically to create conditions of high vulnerability. A climate shock or stress has the potential to do the most damage in a context in which natural systems are being severely stressed and degraded by overuse and in which social, economic or governance systems are in or near a state of failure and thus not capable of effective responses.

Unfortunately, such conditions exist in many parts of the world, particularly the developing world. Places where this is true are consequently vulnerable to some of the high-level concern outcomes from exposure to climate stresses, both now, from current climate variations and extremes, and increasingly in the future as the climate changes. An exception is the potential loss of some ecosystems or their biodiversity, which might in some instances be triggered by climate change alone. For example, the rate of climate change is a key factor that threatens the succulent karoo biome of South Africa, and a rapid rate of change could by itself be sufficient to cause its demise. But for many other ecosystems it will be the interaction of a changing climate with pressures from human uses and management of land and other resources that will probably determine their fate.

More optimistically, our studies suggest that the potential severity and risk of many of the outcomes are less where social, economic and governance systems function in ways that enable effective responses to prevent, cope with, recover from and adapt to adverse impacts. For example, a healthcare system that is effective in delivering services to a population, combined with public health programmes that promote preventive behaviours, disease monitoring and disease vector control, can substantially limit the risk that climate change would cause widespread and persistent epidemics. Disaster prevention, preparedness, early warning and response systems can similarly help to limit the extent of harm from changes in the frequency or severity of extreme climate events. Poverty reduction can provide households with access to all manner of resources that can help them to cope with and overcome climate-related impacts.

These and other examples indicate that improving the performance of human systems can reduce vulnerability. Doing so can yield near-term payoffs, as we improve our management of existing climate risks, as well as the longer-term benefits associated with building resilience to a changing climate. But optimism should be tempered by the reality of how challenging it has been to achieve even minimal progress where key human systems have been dysfunctional.

2.9 References

Adejuwon, J.O. 2008. Vulnerability in Nigeria, a national level assessment. In N. Leary, C. Conde, J. Kulkarni, A. Nyong and J. Pulhin, eds., *Climate Change and Vulnerability*. Earthscan, London, UK.

Anandacoomaraswamy, A., B.R.S.B. Basnayake, M.T.N. Fernando, A.A. Jayakody, T.S.G. Peiris, C.S. Ranasinghe, J. Ratnasiri, A.M.A. Wijeratne, and M.K.S.L.D. Amarathunga. 2008. Vulnerability of Sri Lankan tea plantations to climate change. In N. Leary, C. Conde, J. Kulkarni, A. Nyong and J. Pulhin, eds., *Climate Change and Vulnerability*. Earthscan, London, UK.

Arnell, N.W. 2004. Climate change and global water resources: SERES emissions and socioeconomic scenarios. *Global Environmental Change* 14, 31-52.

Arntzen, J., O.P. Dube and M. Muchero. 2004. Global Environmental Change and Food Provision In Southern Africa: Explorations For A Possible Gecafs Research Project In Southern Africa. http://gecafs.org/outputs/.

Aron, J.L and Patz, J.A. 2001. *Ecosystem change and public health. A global perspective*. John Hopkins University Press. Baltimore.

Barros, V. 2008. Adaptation to climate trends: lessons from the Argentine experience. In N. Leary, J. Adejuwon, V. Barros, I. Burton, J. Kulkarni, R. Lasco, eds., *Climate Change and Adaptation*. Earthscan, London, UK.

Barros, V., A. Menéndez, C. Natenzon, R. Kokot, J. Codignotto, M. Re, P. Bronstein, I. Camilloni, S.G. González, D. Ríos and S. Ludueña. 2008. Climate change vulnerability to floods in the metropolitan region of Buenos Aires. In N. Leary, C. Conde, J. Kulkarni, A. Nyong and J. Pulhin, eds., *Climate Change and Vulnerability*. Earthscan, London, UK.

Batima, P., L. Natsagdorj, and N. Batnasan. 2008. Vulnerability of Mongolia's pastoralists to climate extremes and change. In N. Leary, C. Conde, J. Kulkarni, A. Nyong and J. Pulhin, eds., *Climate Change and Vulnerability*. Earthscan, London, UK.

Camilloni, I.A. and Barros, V.R. 2003. "Extreme discharge events in the Parana River and their climate forcing." *J. of Hydrology* 278: 94-106.

Chinvanno, S., S. Boulidam, T. Inthavong, S. Souvannalath, B. Lersupavithnapa, V. Kerdsuk and N. Thuan. 2008. Climate risks and rice farming in the lower Mekong River basin. In N. Leary, C. Conde, J. Kulkarni, A. Nyong and J. Pulhin, eds., *Climate Change and Vulnerability*. Earthscan, London, UK.

Conde, C., M. Vinocur, C. Gay, R. Seiler, and F. Estrada. 2008. Climatic threat spaces in Mexico and Argentina. In N. Leary, C. Conde, J. Kulkarni, A. Nyong and J. Pulhin, eds., *Climate Change and Vulnerability*. Earthscan, London, UK.

Donne, J. 1623. Devotions Upon Emergent Occasions, Meditation No. 17.
(http://www.incompetech.com/authors/donne/bell.html)

Downing, T.E., 2002. Linking sustainable livelihoods and global climate change in vulnerable food systems. *Die Erde*. 133. 363 – 378.

Dube, P., and M. Sekhwela. 2008. Indigenous knowledge, institutions and practices for coping with variable climate in the Limpopo basin of Botswana. In N. Leary, J. Adejuwon, V. Barros, I. Burton, J. Kulkarni and R. Lasco, eds., *Climate Change and Adaptation*, Earthscan, London, UK.

Eakin, H., M. Wehbe, C. Avila, G.S. Torres, and L.A. Bojorquez-Tapia. 2008. "Social vulnerability of farmers in Mexico and Argentina." In N. Leary, C. Conde, J. Kulkarni, A. Nyong and J. Pulhin, eds., *Climate Change and Vulnerability*. Earthscan, London, UK.

Githeko, A.K., Lindsay, S.W., Confaloniero, U.E. and Patz, J.A.: 2000, 'Climate Change and Vector-Borne Disease: A Regional Analysis', *Bulletin of the World Health Organization*, 78 (9), 1136-1147.

Gleick, P.H. et al, 2000. Water: the potential consequences of climate variability and change for the water resources of the United States. Report for the US. Global Change Research Program, September 2000.

Hay, J., N. Mimura, J. Cambell, S. Fifita, K. Koshy, R.F. McLean, T. Nakalevu, P. Nunn, and N. deWet.. 2003. *Climate Variability and Change and Sea-level Rise in the Pacific Islands Region*. A Resource book for policy and decision makers, educators and other stakeholders. South Pacific Regional Environment Programme (SPREP), Apia, Samoa, 94 pp.

Heslop-Thomas, C., W. Bailey, D. Amarakoon. A. Chen, S. Rawlins, D. Chadee, R. Crosbourne, A. Owino, K. Polson, C. Rhoden, R. Stennett and M. Taylor. 2008. Vulnerability to dengue fever in Jamaica. In N. Leary, C. Conde, J. Kulkarni, A. Nyong and J. Pulhin, eds., *Climate Change and Vulnerability*. Earthscan, London, UK.

Hoerling, M.P., J.W. Hurrell, and J. Eischeid. 2006. "Detection and attribution of 20th century northern and southern African monsoon change." *J. of Climate* 19:3989-4008.

IPCC. 2001a. 'Summary for policymakers'. In J. T. Houghton, Y. Ding, D.J. Griggs, M. Noguer, P.J. van der Linden, X. Dai, K. Maskell, and C.A. Johnson, eds., *Climate Change 20001: The Scientific Basis*. Cambridge University Press, Cambridge, UK and New York, USA.

IPCC. 2001b. 'Summary for policymakers'. In J. McCarthy, O. Canziani, N. Leary, D. Dokken and K. White, eds., *Climate Change 2001: Impacts, Adaptation and Vulnerability*. Cambridge University Press, Cambridge, UK and New York, USA.

IPCC. 2007. 'Summary for policymakers'. In M. Parry, O. Canziani, J. Palutikof and P. van der Linden (eds), *Climate Change 2007: Impacts, Adaptation and Vulnerability*, contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, UK, and New York.

Kilian, A.H.D., Langi, P., Talisuna A. and Kabagambe, G. 1999. "Rainfall Pattern, El Niño and Malaria in Uganda", *Transactions of the Royal Society of Tropical Medicine and Hygiene*, 93, 22-23.

Lasco, R., F. Pulhin, R. Cruz, J. Pulhin, S. Roy and P. Sanchez. 2008. Forest responses to changing rainfall in the Philippines. In N. Leary, C. Conde, J. Kulkarni, A. Nyong and J. Pulhin, eds., *Climate Change and Vulnerability*. Earthscan, London, UK.

Leary, N., C. Conde, J. Kulkarni, A. Nyong and J. Pulhin, editors. 2008a. *Climate Change and Vulnerability*. Earthscan, London, UK.

Leary, N., J. Adejwon, V. Barros, I. Burton, J. Kulkarni and R. Lasco, editors. 2008b. *Climate Change and Adaptation*. Earthscan, London, UK.

Leary, N. 2002. "AIACC, contributing to a second generation of climate change assessments." START Network News, Issue No. 7, May 2002.

Lindblade, K.A., Walker, E.D., Onapa, A.W., Katunge, J. and Wilson, M.L. 2000. "Land Use Change Alters Malaria Transmission Parameters by Modifying Temperatures in a Highland Area of Uganda", *Tropical Medicine and International Health*, 5 (4), 263-274.

Lindblade, K.A., Walker, E.D., Onapa, A.W., Katunge, J. and Wilson, M.L. 1999. "Highland Malaria in Uganda: Prospective Analysis of an Epidemic Associated with El Niño", *Transactions of the Royal Society of Tropical Medicine and Hygiene*, 93, 480-487.

Lindsay, S. W. and Martens, W. J. M. 1998. "Malaria in the African Highlands: Past, Present and Future", *Bullentin of the World Health Organization* 76:33-45.

Mataki, M., K. Koshy and V. Nair (2006) 'Implementing climate change adaptation in the Pacific islands: Adapting to present variability and extreme weather events in Navua, Fiji', AIACC Working Paper No 34, International START Secretariat, Washington, DC, www.aiaccproject.org.

Mataki, M., K. Koshy, R. Lata and L. Ralogaivau (2005) 'Vulnerability of a coastal township to flooding associated with extreme rainfall events in Fiji', unpublished working paper, University of the South Pacific, Suva, Fiji.

McMichael, A., Githeko, A., Akhtar, R., Carcavallo, R., Gubler, D., Haines, A., Kovats, R.S., Martens, P., Patz, J., and Sasaki, A. 2001. "Human Health," in J. McCarthy, O. Canziani, N. Leary, D. Dokken and K. White, eds.. *Climate Change 2001: Impacts, Adaptation and Vulnerability*. Cambridge University Press, Cambridge, UK and New York, USA.

Millennium Ecosystem Assessment. 2005. *Ecosystems and Human Well-being: Synthesis*. Island Press, Washington, DC.

Morgan, M.G., B. Fischhoff, A. Bostrom and C. Atman. 2002. *Risk Communication: A mental models approach*, Cambridge University Press, New York.

Nagy, G.J., M. Bidegain, R.M. Caffera, F. Blixen, G. Ferrari, J.J. Lagomarsino, C.H. López, W. Norbis, A. Ponce, M.C. Presentado, V. Pshennikov, K. Sans and G. Sención. 2008. Climate and water quality in the estuarine and coastal fisheris of the Rio de la Plata. In N. Leary, C. Conde, J. Kulkarni, A. Nyong and J. Pulhin, eds., *Climate Change and Vulnerability*. Earthscan, London, UK.

Nyong, A., D. Dabi, A. Adepetu, A. Berthe, and V.C. Ihemegbulem. 2008. Vulnerability in the Sahelian zone of northern Nigeria, a household level assessment. In N. Leary, C. Conde, J. Kulkarni, A. Nyong and J. Pulhin, eds., *Climate Change and Vulnerability*. Earthscan, London, UK.

Osman-Elasha, B., and A. Sanjak. 2008. Livelihoods and drought in Sudan. In N. Leary, C. Conde, J. Kulkarni, A. Nyong and J. Pulhin, eds., *Climate Change and Vulnerability*. Earthscan, London, UK.

Otinda, P. A.1997. "Desertification: can it be combated?" *Impact, Newsletter of the Climate Network Africa*. No.21, Kenya.

Payet, R.A. 2008. "Climate change and the tourism dependent economy of the Seychelles". In N. Leary, C. Conde, J. Kulkarni, A. Nyong and J. Pulhin, eds., *Climate Change and Vulnerability*. Earthscan, London, UK.

Pulhin, J.M., R. Peras, R. Cruz, R. Lasco, F. Pulhin, and M. Tapia. 2008. Climate variability and extremes in the Pantabangan-Carranglan watershed of the Philippines, an assessment of vulnerability. In N. Leary, C. Conde, J. Kulkarni, A. Nyong and J. Pulhin, eds., *Climate Change and Vulnerability*. Earthscan, London, UK.

Scholes, R.J. and R. Biggs, eds. 2004. Ecosystems services in southern Africa: a regional assessment. Southern African Millennium Ecosystem Assessment. Council for Scientific and Industrial Research, Pretoria, South Africa. 84 p.

Sheppard, C., D.J. Dixon, M. Gourlay, A. Sheppard, and R. Payet. 2005. "Coral mortality increases wave energy reaching shores protected by reef flats: examples from the Seychelles." *Estuarine, Coastal and Shelf Science* 64:223-234.

Travasso, M.I., G.O. Magrin, W.E.Baethgen, J.P. Castaño, G.R. Rodriguez, J.L. Pires, A. Gimenez, G.Cunha, M.Fernandez. 2008. Maize and soybean cultivation in Southeastern South America, adapting to climate change. In N. Leary, J. Adejwon, V. Barros, I. Burton, J. Kulkarni and R. Lasco, eds., *Climate Change and Adaptation*. Earthscan, London, UK.

UNCCD. 2005a. Fact Sheet 3: The consequences of desertification. www.unccd.int/publicinfo/factsheets.

UNCCD. 2005b. Fact Sheet 1: An introduction to the United Nations Convention to Combat Desertification. http://www.unccd.int/publicinfo/factsheets.

von Maltitz, G.P., and R.J. Scholes. 2008. Vulnerability of Southern African biodiversity to climate change. In N. Leary, C. Conde, J. Kulkarni, A. Nyong and J. Pulhin, eds., *Climate Change and Vulnerability*. Earthscan, London, UK.

Yin, Y., N. Clinton, B. Luo, and L. Song. 2008. Resource system vulnerability to climate stresses in the Heihe River basin of Western China. In N. Leary, C. Conde, J. Kulkarni, A. Nyong and J. Pulhin, eds., *Climate Change and Vulnerability*. Earthscan, London, UK.

Walsh, J.F., Molyneux, D.H., and Birley, M.H. 1993. "Deforestation: Effects on Vector-Borne Disease," *Parasitology*, 106, S55-S75.

Wandiga, S.O., M. Opondo, D. Olago, A. Githeko, F. Githui, M. Marshall, T. Downs, A. Opere, P.Z. Yanda, R. Kangalawe, R. Kabumbuli, J. Kathuri, E. Apindi, L. Olaka, L. Ogallo, P. Mugambi, R. Sigalla, R. Nanyunja, R. Baguma, and P. Achola. 2008. Vulnerability to climate induced highland malaria in East Africa. In N. Leary, C. Conde, J. Kulkarni, A. Nyong and J. Pulhin, eds., *Climate Change and Vulnerability*. Earthscan, London, UK.

Ziervogel, G., A. Nyong, B. Osman-Elasha, C. Conde, T.E. Downing, and Cortés, S. 2008. Household food security and climate change: comparisons from Nigeria, Sudan, South Africa and Mexico. In N. Leary, C. Conde, J. Kulkarni, A. Nyong and J. Pulhin, eds., *Climate Change and Vulnerability*. Earthscan, London, UK.

3 A Stitch in Time: Lessons for Climate Change Adaptation from the AIACC Project

Authors: Neil Leary, James Adejuwon, Vicente Barros, Punsalmaa Batima, Bonizella Biagini, Ian Burton, Suppakorn Chinvanno, Rex Cruz, Daniel Dabi, Alain de Comarmond, Bill Dougherty, Pauline Dube, Andrew Githeko, Ayman Abou Hadid, Molly Hellmuth, Richard Kangalawe, Jyoti Kulkarni, Mahendra Kumar, Rodel Lasco, Melchior Mataki, Mahmoud Medany, Mansour Mohsen, Gustavo Nagy, Momodou Njie, Jabavu Nkomo, Anthony Nyong, Balgis Osman-Elasha, Elamin Sanjak, Roberto Seiler, Michael Taylor, Maria Travasso, Graham von Maltitz, Shem Wandiga, and Monica Wehbe

3.1 Introduction

We can adapt to climate change and limit the harm. Or we can fail to adapt and risk much more severe consequences. How we respond to this challenge will shape the future in important ways.

The climate is already hazardous and always has been. Variations and extremes of climate disrupt our production of food and our supplies of water, reduce our incomes, damage our homes and property, impact our health, even take our lives. Humans, in an unintended revenge, are getting back at the climate by adding to heat trapping gases in the Earth's atmosphere that are changing the climate. But the changes are amplifying the hazards to humans. We cannot in short order stop this. The physical and social processes of climate change have a momentum that will continue for decades and well beyond.

This undeniable momentum does not imply that efforts to mitigate climate change, that is to reduce or capture the emissions of greenhouse gases that drive climate change, are wasted. Nor is a call for adaptation a fatalistic surrender to this truth. The magnitude and pace of climate change will determine the severity of the stresses to which the world will be exposed. Slowing the pace of human caused climate change, with the aim of ultimately stopping it, will enable current and future generations to better cope with and adapt to the resulting hazards, thereby reducing the damages and danger. Mitigating climate change is necessary. Adapting to climate change is necessary too.

The challenges are substantial, particularly in the developing world. Developing countries have a high dependence on climate sensitive natural resource sectors for livelihoods and incomes and the changes in climate that are projected for the tropics and sub-tropics, where most developing countries are found, are generally adverse for agriculture (IPCC, 2001 and 2007a). Furthermore, the means and capacity to adapt to changes in climate are scarce due to low levels of human and economic development and high rates of poverty. These conditions combine to create a state of high vulnerability to climate change in much of the developing world.

To better understand who and what are vulnerable to climate change, and to examine adaptation strategies, a group of case studies were undertaken as part of an international project, Assessments of Impacts and Adaptations to Climate Change (AIACC). The studies span Africa, Asia, Central and South America, and islands of the Caribbean, Indian and Pacific Oceans. They include assessments of agriculture, rural livelihoods, food security, water resources, coastal zones, human health and biodiversity conservation. Results from the studies about the nature, causes and distribution of climate change vulnerability are presented in Chapter 2 of this report. Here, in this chapter, we explore findings about the challenge of adaptation.

Adaptation to climate is not new. People, property, economic activities and environmental resources have always been at risk from climate hazards and people have continually sought ways of adapting. Broadly speaking, we are adapted to cope with a wide range of climatic conditions and stresses. But variations and extremes do regularly exceed coping ranges, too often with devastating effect. While climate impacts can never be reduced to zero, the heavy and rising toll of weather-related disasters and the burden of less severe variations indicate that we are not as well adapted as we might or should be. There is, at present, an adaptation deficit.

All the AIACC case studies find evidence of an adaptation deficit in their study areas. But they also find and document a variety of adaptive practices in use that have reduced vulnerability to climate hazards. In most cases these have been adopted in response to multiple sources of risk and only rarely to climate risk alone. General strategies in use in the study areas include increasing the capacity to bear losses by accumulating food surpluses, livestock, financial savings and other assets; hedging risks by diversifying crops, income sources, food sources and locations of production activities; reducing exposures to climate hazards by relocating, either temporarily or permanently; spreading risks through kinship networks, pooled community funds, insurance and disaster relief; reducing the sensitivity of production and incomes derived from natural resources by restoring degraded lands, using drought resistant seed varieties, harvesting rainfall, adopting irrigation and using seasonal forecasts to optimize farm management; preventing climate impacts through flood control, building standards and early warning systems; and increasing the capacity to adapt through public sector assistance such as extension services, education, community development projects, and credit services.

These and other strategies in use are evidence that the vulnerable can and do act to reduce their vulnerability to climate hazards. They also provide a rich base of experience on which to build for adapting to future climate change. But climate change is altering exposures to climate hazards. The frequency, variability, seasonal patterns, spatial distribution and other characteristics of climate events and phenomena are changing. The changes will push future climate variations and extremes outside the bounds of what people have been exposed to and had to cope with in the past. An implication is that current practices, processes, systems and infrastructure that are more or less adapted to the present climate will become increasingly inappropriate and maladapted as the climate changes. That is, the adaptation deficit is likely to grow. Fine-tuning current strategies to reduce risks from historically observed climate hazards would not be sufficient in this dynamically changing environment. More fundamental adjustments will be needed. This will require recognizing what changes are happening, predicting the range of likely future changes, understanding the vulnerabilities and potential impacts, identifying appropriate adjustments, and mobilizing the resources and will to implement them.

Comparison and synthesis of the individual case studies have yielded nine general lessons about adaptation, as well as many more lessons that are specific to particular places and contexts. The general lessons, formulated as recommendations, are: (1) adapt now, (2) create conditions to enable adaptation, (3) integrate adaptation with development, (4) increase awareness and knowledge, (5) strengthen institutions, (6) protect natural resources, (7) provide financial assistance, (8) involve those at risk, and (9) use place-specific strategies. The lessons are briefly outlined below, followed by a more detailed examination of their nuances and supporting evidence from the case studies.

3.2 Nine Adaptation Lessons

3.2.1 Adapt Now!

The time-honoured proverb "a stitch in time saves nine" means that immediate action to repair damage (to your clothing in the original context) can avoid the necessity to do much more later on, as much as nine times more. The expression captures one of the main findings of the AIACC program of studies. It can simply be stated as the injunction to adapt now.

Climatic variations and extremes cause substantial damages to households, communities, natural resources and economies. In many places the damages are increasing, giving evidence of an adaptation deficit, meaning that practices in use to manage climate hazards are falling short of what can be done (Burton, 2004). We find evidence in all our case study sites of an adaptation deficit that climate change threatens to widen. Climate change threatens to widen the deficit. Acting now to narrow the deficit can yield immediate benefits. It will also serve as a useful, even essential, first step in a longer-term process of adapting to a changing climate. Failure to tackle adaptation vigorously now likely would require many more than nine stitches in the future.

3.2.2 Create conditions to enable adaptation

In contrast to reducing emissions of the greenhouse gases that drive climate change, a policy that, in the parlance of economists, generates benefits that are substantially external, adaptation generates benefits that are largely internal. This means that the individuals, organizations, communities and countries that take action to adapt will capture for themselves most of the benefits of their actions, creating a strong incentive to adapt. This explains why we observe a wide range of practices being used to manage and reduce climate risks. But why then do we nonetheless observe adaptation deficits? Why doesn't self-interest motivate people to do more to protect themselves from climate hazards?

There are numerous obstacles that are found to impede adaptation in our case studies. Common obstacles include competing priorities that place demands on scarce resources, poverty that limits capacity to adapt, lack of knowledge, weak institutions, degraded natural resources, inadequate infrastructure, insufficient financial resources, distorted incentives and poor governance. Obstacles such as these severely constrain what people can and are observed to do. Intervention by public sector entities, at levels from the local community to provincial, national and international can create conditions that better enable people to surmount the obstacles and take actions to help themselves. Enabling the process of adaptation is the most important adaptation that the public sector can make. Specific interventions to enable adaptation are addressed by some of the other lessons that follow.

3.2.3 Integrate adaptation with development

The goals and methods of climate change adaptation and development are strongly complementary. The impacts of current climate hazards and projected climate change threaten to undermine development achievements and stall progress toward important goals. Adaptation can reduce these threats. In turn, development, if appropriately planned, can help to enable climate change adaptation. Integrating adaptation with development planning and actions can exploit the complementarities to advance both adaptation and development goals. To be effective, integration needs to engage ministries that are responsible for development, finance, economic sectors, land and water management, and provision of public health and other services. It is in agencies such as these that key decisions are taken about the allocation of financial and other resources. And it is within these agencies and among their stakeholders where much of the sector-specific expertise that must be engaged resides.

3.2.4 Increase awareness and knowledge

Nearly all the case studies highlighted knowledge as a critical constraint on adaptation and rank efforts to increase and communicate knowledge as a high priority for adaptation. Stakeholders in many of the study areas complained of inadequate or lack of access to information about historical climate, projections of future climate change and potential impacts, estimates of climate risks, causes of vulnerability, technologies and measures for managing climate risks, and know-how for implementing new technologies. Uncertainty about the future and about the effectiveness and costs of adaptation options are common obstacles to action. Examination of these and other information problems in the case studies demonstrate the need for programs to help advance, communicate, interpret and apply knowledge for managing climate risks.

3.2.5 Strengthen institutions

Institutions are found to play important roles for enabling adaptation. Local institutions, including modern organizations, informal associations, kinship networks and traditional institutions, serve functions in communities that help to limit, hedge and spread risks. They do this by sharing knowledge, human and animal labor, equipment and food reserves; mobilizing local resources for community projects and public works; regulating use of land and water; and providing education, marketing, credit, insurance and other services. Provincial, national and international institutions aid by providing extension services, training, improved technologies, public health services, infrastructure to store and distribute water, credit, insurance, financial assistance, disaster relief, scientific information, market forecasts, weather forecasts and other goods and services.

In many of our case study sites, key functions for managing risks are absent or are inadequate due to weak institutions that are poorly resourced, lacking in human capacity, overloaded with multiple responsibilities, and overwhelmed by the demands of the communities that they serve. Strengthening institutions to fill strategic functions in support of adaptation is needed. In some instances, traditional institutions that have been diminished in role by socioeconomic changes and government policies provide a remnant framework that could be revitalized to facilitate adaptation and management of climate risks.

3.2.6 Protect natural resources

Developing countries typically are dependent on climate sensitive natural resources for a high proportion of their livelihoods, economic activities and national incomes. Too often these resources are in a degraded state from a combination of pressures caused by human use and climatic and environmental variation and change. Their degraded state makes these resources, and the people who are dependent on them, highly vulnerable to damages from climate change. Rehabilitating and protecting natural resources such as farm lands, grazing lands, forests, watersheds, wetlands, fisheries and biodiversity are a central focus of adaptation strategies in places as varied as the African Sahel, southern Africa, central Asia, southeast Asia, and south-eastern South America. Progress in many of these settings will require changes in incentives, reforms of tenure to land, water and natural products, education, training, and more vigorous enforcement of regulations. These in turn are dependent upon strong institutions and access to financial resources.

3.2.7 Provide financial assistance

Lack of financial resources is commonly cited as a major obstacle to adaptation. The constraint is particularly binding on the poor and the very poor, who typically are among the most vulnerable to climate change. Poor households and small-scale farmers and enterprise owners obtain finance through community and informal networks to recover from losses and make investments that reduce risks. But more adaptation could take place in impoverished localities and regions with greater financial assistance from provincial and national governments and international sources. Innovative ideas are needed for engaging the private sector in financing adaptation. Internationally, some financial assistance is being provided and acts as a catalyst for raising awareness, building capacity and advancing understanding of risks and response options. But the magnitude of financial needs for adaptation is much greater than the current level of assistance. Increased financial assistance over and above normal development assistance is needed. Ultimately, however, financing will need to come from multiple sources, including those internal to developing countries.

3.2.8 Involve those at risk

Involving persons at risk in the process of adaptation, the intended beneficiaries, can increase the effectiveness of adaptation to climate change. Many of our case studies involved at-risk groups in assessment activities. The experiences demonstrate the potential of participatory approaches to adaptation for focusing attention on risks that are priorities to the vulnerable, learning from risk management practices currently in use, identifying opportunities and obstacles, applying evaluation criteria that are relevant and credible to at-risk groups, drawing upon local knowledge and expertise for selecting and designing appropriate strategies, garnering support and mobilizing local resources and cooperation to assist with implementation. A common result of involving those at risk is that it forces climate risks to be examined in context with other problems and gives emphasis to solutions that can be combined to attain multiple objectives.

3.2.9 Use place-specific strategies

Adaptation is place-based and requires place-specific strategies. This fact has long been recognized in the climate impacts research literature. The general lessons outlined above conceal a much richer content of the case studies and risk presenting an oversimplified story. The ninth lesson is that there are many more lessons and that many are specific to particular contexts of particular places.

For example, in the lower Mekong River basin, rice farmers face similar risks from floods but rely on different strategies for managing the risks that reflect differences in the level of economic development of their surrounding community, strength of community institutions, locally available natural resources and differences in seasonal rain patterns (Chinvanno et al, 2008). Pastoralists in Mongolia, Sudan and Botswana share some strategies for coping with drought that have general characteristics in common, but there are significant differences too that derive from different traditions, resources and climates (Batima et al, 2008; Osman-Elasha et al, 2008; and Dube et al, 2008). People living in the Caribbean and the highlands surrounding Lake Victoria both face health risks from mosquito-borne diseases that vary with the climate, but differences in public health infrastructure and access to health care contribute to differences in responses to the diseases (Taylor et al, 2008, and Yanda et al, 2008). General lessons can be applied in these different settings to help guide adaptive strategies, but details of the local context will determine the specific approaches and measures that will be most effective in each place.

3.3 Adaptation Now and in the Future

3.3.1 What is adaptation?

The Intergovernmental Panel on Climate Change (IPCC) defines adaptation as adjustments in ecological, social or economic systems in response to actual or expected climatic stimuli and their effects (Smit et al, 2001). It includes adjustments to moderate harm from, or to benefit from, current climate variability as well as anticipated climate change. Adaptation can be a specific action, such as a farmer switching from one crop variety to another that is better suited to anticipated conditions. It can be a systemic change such as diversifying rural livelihoods as a hedge against risks from variability and extremes. It can be an institutional reform such as revising ownership and user rights for land and water to create incentives for better resource management. Adaptation is also a process. The process of adaptation includes learning about risks, evaluating response options, creating the conditions that enable adaptation, mobilizing resources, implementing adaptations, and revising choices with new learning. We mean all these things by adaptation. But the conception of adaptation as a process is often the most important for formulating public interventions that will have lasting benefits.

3.3.2 Is adaptation new?

Adaptation to climate is not new. People, property, economic activities and environmental resources have always been at risk from climate and people have continually sought ways of adapting, sometimes successfully and sometimes not. The long history of adapting to variations and extremes of climate includes crop diversification, irrigation, construction of water reservoirs and distribution systems, disaster management and insurance, and even includes, on a limited basis, recent measures to adapt to climate change (Adger et al, 2007).

The AIACC case studies document a variety of adaptive practices in use that have reduced vulnerability to climate hazards. In most cases, these have been adopted in response to multiple sources of risk and only rarely to climate risk alone. One strategy commonly in use is to increase the capacity to bear losses by accumulating food surpluses, livestock, financial assets and other assets. Risks are hedged by diversifying crops, income sources, food sources and locations of production activities. Exposures to climate hazards have been reduced by relocating, either temporarily or permanently. Variability of production and incomes derived from natural resources have been reduced by restoring degraded lands, using drought resistant seed varieties, harvesting rainfall, adopting irrigation and using seasonal forecasts to optimize farm management. Prevention of climate impacts with flood control, building standards and early warning systems is practiced. Risk spreading is accomplished through kinship networks, pooled community funds, insurance and disaster relief. In many cases the capacity to adapt is increased through public sector assistance such as extension services, education, community development projects, and access to subsidized credit.

3.3.3 Is adapting to climate change different?

Is adapting to climate change different? Yes and no. Coping with and adapting to climate have always faced an uncertain future. Human societies have long coped with floods, droughts and other climate hazards without knowing when the next event would occur, how big it would be or how long it would last. Past experience provided a basis, albeit imperfect, for approximating the frequencies of events of different magnitudes and the likely range of conditions that might be encountered in the coming season, year or decade.

But climate change means that past performance of the climate is becoming a less reliable predictor of future performance. The frequency, variability, seasonal patterns and characteristics of climate events and phenomena will change. Phenomena once alien to a region could become regular features of its climate (for example, extra-tropical storm tracks are projected to move poleward, IPCC, 2007b). An important consequence of climate change for adaptation is that the future climate will be less familiar and in key respects more uncertain.

However, some climate parameters will change with predictable trends as a result of human-driven climate change. Globally averaged surface temperatures are projected to rise 1.1-6.4^{o}C by end of the 21st century relative to 1980-1999 temperatures (IPCC, 2007b). Annual and monthly average temperatures can be expected to increase virtually everywhere with a very high degree of confidence. Trends in average precipitation are also projected but vary from decreases to increases depending on location and season. While confidence in predictions of precipitation trends is less than for temperature trends, some broad patterns do seem to be robust across climate model projections. For example, precipitation is very likely to increase in high-latitudes while decreases are thought likely in most subtropical land areas. Likely trends for extreme weather include more frequent hot days, heat waves and heavy precipitation events; more intense tropical cyclones with greater peak wind speeds and heavier precipitation; and increased summer drying and drought risk in continental interiors. The projected trends in temperature, precipitation, and extremes will push future climate variations and extremes beyond the bounds of what people and places have been exposed to and had to cope with in the past.

The implication is that current practices, processes, systems and infrastructure that are more or less adapted to the present climate will become increasingly inappropriate and maladapted as the climate changes. Fine-tuning current strategies to reduce risks from historically observed climate hazards will not be sufficient in this dynamically changing environment. More fundamental adjustments will be needed. This will require recognizing what changes are happening, predicting the range of likely future changes, understanding the vulnerabilities and potential impacts, identifying appropriate adjustments, and mobilizing the resources and will to implement them.

The experiences of Argentina in the last decades of the 20th century are instructive of some of the challenges (Barros, 2008). A number of climate trends are documented that began in the 1960s and 1970s. These include large increases in mean annual precipitation in southern South America east of the Andes Cordillera; increased flows and flood frequencies of the major rivers of the region, the Parana, Paraguay and Uruguay Rivers; more frequent heavy rainfall events in central and eastern Argentina resulting in localized flooding; more frequent *sudestadas* which bring winds from the southeast that cause high tides and flooding in Buenos Aires; and, in western Argentina, declining rainfall and stream flows.

The speed and effectiveness of adaptive responses to these trends varied. In each case there was a lag between the onset of the climate trend and recognition by affected persons, government agencies and the public. The lag varied depending on the perception of impacts, their magnitude, natural variability of the climate phenomenon, adequacy of observational data, and the difficulty of detecting trends in low frequency events. In all cases recognition was not immediate and the shortest lag time was roughly ten years. The quickest response came in the case of increased rainfall east of the Andes but west of the traditional crop farming areas. Farmers recognized and acted on the new opportunity created by the greater rainfall, as well as by high soybean prices in international markets, to profitably cultivate lands that were previously too dry for crop farming. This resulted in significant westward expansion of crop farming, particularly of soybeans. Less quick to act was the government, which failed to provide road and other infrastructure to support the westward expansion of crop farming.

Usually emphasis is placed on uncertainty of predicted climate change as a barrier to adaptation. Less appreciated is the barrier created by uncertainty in detecting changes that are already underway and likely to continue. The examples from Argentina demonstrate how delays in recognition and limited awareness of climate trends by key stakeholders delayed adaptive responses. They also suggest that those who have a direct self-interest in adapting may be more astute and quicker to respond.

Biodiversity conservation in southern Africa is an example where climate change will require a fundamental change in approach from current risk management (von Maltitz et al, 2008). In 50 years time, up to half of South Africa will have a climate that is not currently found in that country. With the changes, many species will need to move across the landscape to track climates that are suitable to their requirements. It will no longer be adequate to protect species where they are currently found – conservationists will have to aim for a moving target.

Some species will be able to tolerate the new climate in their current locations (persisters); some will thrive in new climate niches not currently available and expand their ranges (range expanders); some will no longer be viable in part or all of their current range and must disperse to new areas (partial and obligatory dispersers); and some will find no areas with suitable climate and will go extinct from the region (no hopers). Modelling of climate change impacts on *Proteaceae,* a surrogate for the highly diverse fynbos vegetation of South Africa, yields estimates that in 50 years 57 percent of species would be persisters, 26 percent partial dispersers, 6 percent obligatory dispersers, and 11 percent would be no hopers.

The no-hopers can be preserved only by *ex situ* conservation methods. Migration of the obligatory and partial dispersers over a mixed use, fragmented landscape to track a changing climate is not assured. And successful dispersal 50 years from now does not assure long-term survival, as the climate will continue to change. Multiple strategies will be needed to facilitate migration and minimize species loss. Adding to and reconfiguring land reserves are one element that will be needed, but it is a costly approach and the lands needing protection are a moving target. New and more aggressive strategies will be needed to make the landscape more permeable and biodiversity friendly, including private and communal lands that are not in formal reserves.

The terminology from the field of biodiversity conservation, obligatory dispersers and no-hopers, is stark. But are there analogous cases in other contexts? Will climate change make inhabitants of some small islands, coastal areas, and arid zones partial or obligatory dispersers? Is the hope for survival of some small island nation states and their cultures dependent on *ex situ* conservation? Do some livelihoods have no hope of persistence in a changing, more hazardous climate? The methods of adaptation to climate change will often be similar to, borrow heavily from and build upon current adaptation practice. But as these questions suggest, the challenges and stakes are getting higher.

3.3.4 Is current adaptation enough?

Adaptation to climate variation is a regular feature of our lives and, broadly speaking, we are adapted to cope with a wide range of climatic conditions. Indicators of successful adaptation include the increase in world food production in pace with population growth, increased life expectancy and decreased weather related deaths in developed countries (Schneider et al, 2007 and McMichael et al, 2001).

But variations and extremes do regularly exceed coping ranges, too often with devastating effect. Natural hazards, including weather related hazards, result in an average of more than 184 recorded deaths per day (Pelling et al, 2004). During the period 1980-2000, deaths from tropical cyclones, floods and droughts exceeded 250,000, 170,000 and 830,000, respectively, with the overwhelming majority of these deaths occurring in developing countries. Individual events can cause billions of dollars in damages. Economic and insured losses from natural catastrophes have increased more than 6-fold and 24-fold respectively since the 1960s (Munich Re, 2005).

While climate impacts can never be reduced to zero, the heavy toll of weather-related disasters and burden of less severe variations indicate that we are not as well adapted as we might or should be. All of the AIACC case studies give evidence of an adaptation deficit and identify measures that could reduce current losses. For example, greater reforestation efforts and enforcement of forest protection laws would reduce soil erosion and flood risks in the Pantabangan-Caranglan watershed of the Philippines (Lasco et al, 2008). In the Berg River basin of South Africa, allowing greater flexibility for water transfers or water marketing would enable water to be allocated more efficiently during periods of drought (Callaway et al, 2008). A variety of underutilized options for reducing drought and flood risks are available to farmers in Argentina, Botswana, Cambodia, Egypt, Lao PDR, Mexico, Nigeria, Sudan, Thailand and Tunisia (Barros, 2008; Dube et al, 2008; Chinvanno et al, 2008; Mougou et al, 2008; Wehbe et al, 2008; Dabi et al, 2008; and Osman-Elasha et al, 2008). In Jamaica, management of dengue fever risks are largely reactive and could be improved by proactive steps for education, elimination of breeding sites, and early warnings (Taylor et al, 2008). Building sturdier houses raised above ground level, improved control of river siltation and more regular dredging of rivers would reduce flood losses in coastal towns of Fiji (Mataki et al, 2008).

The current deficit in adaptation makes it imperative to adapt now. Doing so would have immediate benefits in reduced weather-related impacts and increased human welfare. The need to adapt is made more urgent by climate change, which is now upon us and is widening the deficit. Adapting to current climate is an essential step towards adapting to future climates.

3.3.5 What are the obstacles to adaptation?

People may not adapt, or adapt incompletely, for a variety of reasons. Climate may be perceived, rightly or wrongly depending on the context, to pose little risk relative to other hazards and therefore given low priority. Knowledge of options to reduce climate risks or the means to implement them may be lacking. Or their expected costs may exceed the expected benefits. The means or capacity to adapt may be lacking. Uncertainty about the future may make it difficult to know what to do or when to do it. Irreversible consequences of some actions may delay choices until some of the uncertainty is resolved. Incentives may be distorted in ways that discourage choices that reduce risks, or even encourage riskier choices. Sometimes the action of others, or inaction of others, can be an obstacle. Some may believe that reducing their own risk is the responsibility of others. All these are found to impede adaptation in one or more of the case studies.

The AIACC studies are all set in developing countries and most focus on places and households that are poor. Poverty, in human development as well as economic terms, is a major obstacle to adaptation in these study areas. Indicative of the constraint imposed by poverty is the high proportion of households in East Africa that do not use insecticide treated bed nets as a prevention against malaria, despite their effectiveness and seemingly low cost (Yanda et al, 2008).

The case studies of northern Nigeria (Dabi et al, 2008) and the states of North Kordafan, North Darfur and Red Sea in Sudan (Osman-Elasha et al, 2008) are illustrative of the constraints faced by poor rural households. Households in their study areas, located in the dry and drought prone Sudano-Sahel zone, typically have low capacity to adapt because of very limited financial, natural, physical, human and social capital. They have little or no cash income, financial savings or access to credit with which to purchase seed, fertilizer, equipment, livestock or food. The lands from which they derive their livelihoods have poor fertility, are highly erodable and are degraded from heavy use, clearing of vegetation, declines in average precipitation and increasing frequency of drought. Physical infrastructure for transportation, communication, water supply, sanitation, and other services are lacking. People have knowledge of many traditional practices for coping with drought and other stresses, but often have little knowledge of new or alternate methods due to poor access to education, training or extension services. Kinship networks provide a safety net for food and other necessities in times of crisis, but sometimes a crisis such as drought or violence will strike many members of a network simultaneously. Local institutions for providing community services are generally weak, governance at provincial and national levels is ineffective, and violence and conflict have heightened vulnerability – with devastating impact in Darfur.

Lack of awareness, information and knowledge is a constraint on adaptation in all of the case studies. In Argentina, as noted previously, lags in recognition of climate trends that had begun in the 1960s and 1970s resulted in delayed and incomplete adaptive responses (Barros, 2008). Tunisian farmers are reluctant to change from inherited traditional practices because they lack knowledge and education to evaluate and implement new methods (Mougou et al, 2008). Similarly, in Tamaulipas, Mexico, *ejidatarios* and smallholder farmers lack know-how for adopting irrigation (Wehbe et al, 2008). In Mongolia, herders voiced a strong need for education and training in methods for improving the condition and productivity of their rangelands and livestock (Batima et al, 2008). Participants in the artisanal fishery of the La Plata estuary need better information about the effects of variations in climate on movements of fish stocks and fish catch, forecasts of fishing conditions, and fishing methods and technologies for managing variability in the fishery (Nagy et al, 2008).

Seasonal weather forecasts and early warning systems are frequently suggested as useful for informing the management of climate risks. But, as shown by Adejuwon et al (2008), they require an effective knowledge network to deliver their promised benefits. Seasonal forecasts are made for West Africa and Nigeria, but few farmers use them. Their reliability is low, the variables forecast are not ones that are most relevant to farmers' decisions, and the spatial resolution of the forecasts is coarse compared to what farmers' need. The forecasts are poorly disseminated, are delivered only shortly in advance of the forecast period, do not regularly reach smallholder farmers, and are in forms that are not readily understood by farmers.

A number of steps can be taken to improve this knowledge network so that farmers are provided with forecasts that they would use. Agricultural extension agents, working with both farmers and forecasters, could help forecasters to focus on the climate variables and spatial resolutions that matter to farmers and provide feedback from farmers to the forecasters about the performance and utility of the forecasts. The extension agents, who are based in over 700 local government units and work in local languages, could develop methods for communicating forecasts to farmers in ways that are useful and understandable. They could assist farmers to interpret and apply forecasts for making decisions such as the timing of planting, choice of crops and crop varieties, and application of fertilizers, herbicides, pesticides and irrigation water. Success will be dependent on cooperation and coordination across the regional and national meteorological agencies, agricultural extension agency, local government units, and farmers' associations, which may require changes in responsibilities, accountability and incentives.

Scarce and degraded natural resources contribute to vulnerability and detract from the capacity to adapt in many of the case studies. Insufficient water supplies, and poor quality of existing supplies, prevent Tunisian farmers from expanding irrigation (Mougou et al, 2008). In some instances, treatment of a resource as an open access commons has contributed to its degradation and created disincentives for adaptations to protect the resource. Following the transition to a market economy in Mongolia, livestock ownership was privatized while pastureland remained state owned and access largely unrestricted (Batima et al, 2008). This has contributed to overstocking of animals, diminished seasonal migration of herds, and lack of investment in land improvements. This situation contrasts with earlier periods during which state collectives, and before that traditional family groups, controlled access to communal pastures.

Social capital, an important resource for coping with risk, has been eroded in many places by social and economic changes and by government policies. In the Limpopo Basin of eastern Botswana, the *Kgotla*, or traditional institution for local decision making and administration of justice, played a central role in adapting the local community to climate variability by regulating resource use and maintaining and disseminating traditional knowledge for the use of veld products (Dube et al, 2008). The *mafisa* system of lending cattle to poorer family members, the marriage institution and family-based user rights to land provided social security and income security that limited risks from climate extremes and other crises. These institutions were weakened during the 20th century, with the result that communities were alienated from decision making about local resource use, income poverty and capability poverty were deepened, and dependence on government interventions increased. This loss of social capital has reduced the capacity of communities to adapt and amplified their vulnerability to climate hazards.

Governance can either constrain or enable adaptation. Financial constraints, already mentioned for households, is one factor that prevents governance from playing a more positive role. Government agencies are often poorly resourced relative to the demands placed on them. Other impediments to government support for adaptation include lack of awareness, knowledge and staff with relevant skills, ineffective administration, poor coordination across departments, inadequate accountability and corruption. Also important is that persons who are most vulnerable to climate risks are often socially and politically marginalized and therefore unable to influence governments to act in their interest.

3.4 Climate and Development

3.4.1 What are the impacts of climate on development?

Weather-related disasters take lives, damage infrastructure and natural resources, and disrupt economic activities. Billions of people are exposed to natural disaster risk in more than 100 countries and more than 1 million people were killed by drought, tropical cyclones and floods during the period 1980-2000 (Pelling et al, 2004). Roughly 90 percent of disaster victims live in developing countries. Economic losses from natural catastrophes are estimated to be US$575 billion over the period 1996-2005, with record losses of US$210 billion reported in 2005 (Re, 2005). In the aftermath of disasters, human development in the impacted communities and wider region is setback and can take years to recover from the loss of housing, businesses, roads, water systems, schools, hospitals, farm fields and livestock. Events such as Hurricanes Mitchell, George and Katrina can cause economic losses that are a significant percentage of national or regional income. Repairing the damage can divert scarce capital from new development projects. Recurrent climate anomalies that do not rise to the level of natural disasters also adversely affect supplies of food and water, incomes, livelihoods, and health and place a drag on economic development.

The projected changes in climate, which include changes in average temperatures and rainfall as well as changes in climate extremes, will have wide ranging impacts. At risk from the projected changes are the productivity of agricultural lands, natural ecosystems and the livelihoods that are dependent on them. Also at risk are water supplies, human health and populations inhabiting low lying coasts, floodplains, steep slopes and other exposed locations (McCarthy et al, 2001). The AIACC case studies illustrate these and other climate risks at national and local scales in a variety of developing country contexts. Not all impacts will be negative. For example, a number of studies, including Travasso et al (2008), find that climate change and higher concentrations of carbon dioxide in the atmosphere are likely to increase yields of important crops in parts of South America. But most studies find that impacts will be predominantly negative in developing regions of the world (McCarthy et al, 2001).

Current climate hazards and the impacts of projected climate change threaten human development (African Development Bank et al, 2003). Climate is linked to all the Millennium Development Goals, but is most directly relevant to the goals to eradicate extreme poverty and hunger, reduce child mortality, combat disease, and ensure environmental sustainability (Martin-Hurtado et al, 2002). Agriculture, which is highly sensitive to climate and which is projected to be negatively impacted by climate change in much of the tropics and sub-tropics, is the direct or indirect source of livelihood for about two-thirds of the population of developing countries and is a substantial contributor to their national incomes. About 70 percent of the world’s poor live in rural areas. Progress on all the Millennium Development Goals will be dependent upon progress in agricultural development and rural development. Management of climate hazards and climate change impacts in the agriculture sector and rural communities will be critical for success.

3.4.2 How does development affect vulnerability to climate?

There is a clear link between development level and vulnerability to climate and other natural hazards. Disaster risk is significantly lower in high income countries than in medium and low income countries. Countries classified as having high human development represent 15 percent of the population that was exposed to natural disasters in 1980-2000 but account for only 1.8 percent of the deaths (Pelling et al, 2004). In comparison, countries with low human development represent 11 percent of the exposed population but account for 53 percent of the recorded deaths.

The association of poverty and low levels of development with high levels of vulnerability are borne out in the AIACC studies. Failures of development to raise people out of poverty causes people to occupy highly marginal lands for farming and grazing, settle in areas susceptible to floods and mudslides, and live with precarious access to water, health care and other services. These conditions contribute to the high degree of vulnerability found among the rural poor of Botswana, Nigeria, Sudan, Thailand, Lao PDR, Vietnam, the Philippines, Argentina and Mexico. Squatter communities in Jamaica and the Philippines are more vulnerable than other communities because of lack infrastructure, access to basic services and social institutions to support collective efforts for reducing risks (Taylor et al, 2008, and Lasco et al, 2008).

Although much of the world continues to live in poverty and at high risk from hunger and disease, human development has greatly reduced vulnerability to climate-driven risks by increasing agricultural productivity, food production and trade, water storage and distribution systems, housing quality, transportation networks, health care, education and wealth. The Millennium Development Goals have set a challenge to expand the benefits of development to include those who continue to live in deep poverty. Moving forward, development that is focused on the poor can reduce vulnerability to climate and other stresses by improving the conditions and capacities of poor households, communities and countries so that they are more resilient to shocks and more capable of responding and adapting. If based on sound principles of resource management, development can improve resource-based rural livelihoods so that they are less sensitive to climate variations and more sustainable.

Development can, however, exacerbate pressures that add to the vulnerability of some. Past practice has given scant consideration to climate risks in planning development projects, resulting in greater vulnerability than what otherwise could have been achieved, even increasing vulnerability in some instances through maladaptive choices (Burton and van Aalst, 2004).

The uneven effects of development can also contribute to vulnerability. Trade liberalization has brought general increases in economic activity, lower prices, and greater overall wealth, but the benefits are unevenly distributed and some have suffered harm. Smallholder farmers and livestock raisers in Argentina and Mexico have struggled to compete as output prices fell relative to the costs of inputs, making them more vulnerable to climate shocks (Wehbe et al, 2008). Falling rice prices from greater productivity in Asia and liberalized trade caused rice farming to be abandoned in Navua, Fiji. The resulting loss of incomes and lack of maintenance of abandoned irrigation channels have raised vulnerability of inhabitants of the township to flood hazards (Mataki et al, 2008).

Development in the Heihe River basin of China has brought greater livelihood opportunities and incomes, but has also increased water demand in this arid basin to the point where water withdrawals are 80 to 120 percent of average annual flows and conflicts have arisen between competing water users (Yin et al, 2008). Social and economic changes have driven rural-to-urban migrations, often concentrating poorer migrants in settlements that are prone to flooding, as is happening on the outskirts of metropolitan Buenos Aires (Barros, 2008). Increasing market orientation, movements of population and government policies have weakened community institutions and diminished use of collective strategies for managing climate risks in places such as Botswana (Dube et al, 2008), countries of the lower Mekong (Chinvanno et al, 2008), Mongolia (Batima et al, 2008), and Sudan (Osman-Elasha et al, 2008). Development projects intended to benefit one group can have spillover effects that harm others, as is the case with the Khor Arbaat dam that is helping to solve water shortage problems in Port Sudan but at the expense of downstream traditional farmers who rely on the intermittent flow of seasonal streams (Osman-Elasha et al, 2008).

3.4.3 Integrating adaptation with development

Sometimes climate change adaptation is seen as competing with the human and economic development needs of the world's poor. Development needs are immediate, the consequences of poverty in countries with low development are appalling, progress is less than desired and allocated resources too little. In comparison, climate change can be perceived as a problem distant in time, uncertain in its effects, and less consequential than present day poverty. Adaptation may therefore seem less urgent and less compelling than increasing development efforts for the world's poor. But, as argued above, climate hazards are immediate, they are growing, they threaten the quality of life and life itself, and they directly impact on the goals of development.

In balancing needs for climate adaptation with those of development, it is critical to note that there is strong complementarity between their goals and methods. A society that is made more climate resilient through proactive adaptation to climate variations, extremes and changes is one in which development achievements and prospects are less threatened by climate hazards and therefore more sustainable. Development can repay the complement by creating conditions that better enable adaptation. This complementarity implies that integration of adaptation efforts with development can yield synergistic efficiencies and benefits that advance the goals of both agendas. This is not to deny that tradeoffs and hard choices may be required. That is the reality of pursuing multiple goals with limited resources. But there are sufficient complementarities to make integration a workable and desirable strategy.

Adaptation activities carried out in isolation from mainstream development and the functions of authorities responsible for managing economic sectors and natural resources may be pragmatic in some contexts. It can help raise awareness, allow experimentation with different methods, and provide proof of concept. But adaptation as a standalone function that is implemented by climate change experts will fail to mobilize the resources and engage the full range of actors that are necessary for success. To create a climate resilient society, adaptation as a process needs to be integrated into the processes of policy formulation, planning, program management, project design and project implementation of the agencies that are responsible for human and economic development, finance, agriculture, forestry, land use, land conservation, biodiversity conservation, water, energy, public health, transportation, housing, disaster management and other sectors and activities.

At the most basic level, integration would avoid maladaptive actions by development and other agencies that fail to account for climate-related risks and thereby unintentionally increase risks or miss easy opportunities to reduce risks. This could be achieved by subjecting policies, programs and projects to initial scrutiny for exposure to climate risks and modifying them accordingly, similar to assessments that are done for environmental impacts, gender equality and poverty reduction. A further step toward integration would be for public sector agencies to promote and support actions and behaviours by individuals, the private sector and civil society that would narrow the current adaptation deficit. Yet more ambitious, but ultimately essential, are development strategies that proactively create conditions to enable adaptation processes by enhancing the capacities of individuals, strengthening community institutions, removing obstacles and providing appropriate incentives.

Many of the AIACC studies demonstrate the need for comprehensive approaches to adaptation that are integrated with broader development strategies and examine how this might be done. They highlight several characteristics of development that would be complementary to the goals of adaptation. These include development that targets highly vulnerable populations, diversifies economic activities, expands opportunities for livelihoods that are less climate sensitive, improves natural resource management, encourages the development and diffusion of technologies that are robust across a wide range of climate variations and extremes, directs development away from highly hazardous locations toward less hazardous ones, and invests in expanding knowledge that is relevant to reducing climate risks.

An examination by Osman-Elasha et al (2008) of community development efforts in Sudanese villages of Bara Province in North Kordafan, El Fashir in North Darfur and Arbaat in the Red Sea State demonstrate that development and adaptation to climate risks can be strongly complementary. Community development projects implemented in the villages integrated multiple strategies to improve livelihoods, the quality of life, and sustainability of resource use within a context of recurrent drought. Using measures of changes in household livelihood assets (human, physical, natural, social and financial capital), the holistic approach to development taken in the study areas are found to have succeeded in increasing the capacity of households to cope with the impacts of drought. Community participation in the projects and reliance on indigenous technologies for improving cultivation, rangeland rehabilitation and water management that are familiar to the communities are found to be important factors for success. The sustainable livelihood approach appears to be a viable model for integrating development and adaptation to climate hazards at the community scale.

Rice farmers in Thailand, Vietnam and Lao PDR rely primarily on their own capacity to implement strategies for coping with floods and mid-season dry spells, which is strongly limited by the social and economic conditions and natural resources in the surrounding community (Chinvanno et al, 2008). Once prevalent collective strategies to pool resources within their communities and provide buffers against food and income losses are much diminished, though still important in Lao PDR. National policies are in general not supportive of reducing the vulnerability of small rice farmers to climate hazards. A national strategy to integrate climate risk management with rural development, poverty reduction and farm policies is recommended for raising the capacity and resilience of farm households and rural communities. Opportunities for effective interventions by national governments include assisting farm households with financial resources, expanding off-farm income opportunities, marketing of farm products, improving access to water, protecting the natural resource base, developing and promoting new technologies to diversify farm incomes, improving seed varieties and providing information about current and changing climate hazards. Revitalizing community institutions is seen as important for enabling communities to benefit from national interventions.

An approach to integrating adaptation and development that is being embraced by Pacific Island Countries such as Fiji also combines top-down and bottom-up strategies (Mataki et al, 2008). Top-down actions would be taken by the national government to create incentives, enforce regulations, assist with capital financing and implement large projects that are beyond the means of local authorities to create a climate-proof society. These actions would encourage and enable development and settlement away from hazardous locations, building of flood-proof homes, purchase of insurance, better land-use practices, and river dredging and maintenance of irrigation channels and floodgates to control flooding. Bottom-up actions would draw on communal traditions of Pacific Island societies to engage members of the community to pool financial, human capital and other local resources and channel these in efforts to reduce climate related risks. The current political framework in Fiji does not provide an effective means for local communities to make their concerns felt at the national level and there is lack of communication and coordination across government departments. These obstacles will need to be overcome for the combined top-down and bottom-up integration to be effective.

3.5 Evaluating Adaptation Options

3.5.1 What to do, how much, when?

Adaptation decisions are made in a context of uncertainty and change. While we can be confident that the climate will change in response to greenhouse gas forcing, there is uncertainty about how it will change and how fast, particularly at the spatial scales that are relevant for adaptation. The impacts are also uncertain, partly because the changes in climate are uncertain, partly because the sensitivities of systems to climate stresses are uncertain, and partly because there is uncertainty about future demographic, social, economic, technological and governance conditions that will shape future exposures, sensitivities, capacities and vulnerabilities. There is also uncertainty about the potential performance of different adaptation options, their costs and possible unintended consequences.

Uncertainty makes it difficult to decide what to do, how much of it to do and when to do it. Many of the choices will have irreversible consequences, so choosing wrong can be costly, even deadly. This is just as true for deciding not to adapt, or to delay adapting, as it is for deciding to adapt now. Delaying adaptation will result in irreversible consequences that could be avoided by adapting now. But not all adaptations could or should be implemented now. Which are appropriate for immediate or near-term action and which should be delayed?

A number of factors are relevant to the selection of options for immediate action. These include the timing of benefits, the dependence of benefits upon specific climate conditions, irreversible consequences, option values, and thresholds for adverse impacts (Leary, 1999). Characteristics of adaptation measutes that warrant consideration for early action include expectation of significant near-term benefits (for example in narrowing existing adaptation deficits), performance that would produce benefits under a wide range of possible future climates, low capital costs, and minimal irreversible consequences. Also of interest for early implementation are actions that would preserve or expand options for future adaptation (for example purchase of development easements and capacity building), or counteract looming thresholds for adverse impacts (for example facilitated migration of species that are obligatory dispersers). Characteristics that would suggest delay of some actions while uncertainties are resolved include little near term benefit, future benefits that depend upon a narrow range of climate conditions, high capital costs and large irreversible consequences.

3.5.2 Evaluation of options by AIACC studies

Decision-making criteria for evaluating and selecting adaptation options vary from context to context. Criteria can vary depending upon who is making the decision, what stakeholders are affected by the decision, what role stakeholders have in the decision process, the objectives of decision makers and stakeholders, and characteristics of the decision such as the time horizon, uncertainty about outcomes, irreversibility of consequences and consequences of decision errors. Criteria applied in the AIACC studies include net economic benefit, timing of benefits, distribution of benefits, consistency with development objectives, consistency with other government policies, cost, environmental impacts, spill-over effects, capacity to implement and social, economic and technological barriers. In some cases the criteria are chosen by the investigators, in other cases they are chosen by stakeholders or based upon stakeholder input. Methods for their application include formal benefit-cost and multi-criteria analysis, expert judgment and participatory exercises with selected stakeholders.

Callaway et al (2008) apply formal benefit-cost analysis to decisions about building water storage and switching water allocation regimes for the Berg River basin in South Africa. The net benefits from choices of reservoir capacity are uncertain and vary depending on how the future unfolds with respect to climate, growth in water demand, and reliance on either the current regulatory regime or water markets for allocating water. The climate scenarios analyzed include no change in surface water runoff and reductions of either 11 or 22 percent. Under the current regulatory regime for water allocation and water demand growth of 3 percent per year, climate change would cause estimated damages with a present discounted value of 13.4 billion to 27.6 billion Rand, or roughly 15 to 30 percent of the total net benefits of water use in the basin. Adapting by correctly anticipating and adjusting reservoir capacity to the optimal size corresponding to the change in climate would reduce the damages and yield net benefits, but the net benefits are modest and less than 2 percent of the damages. In contrast, a switch from the current regulatory regime to allocation by water markets would yield net benefits of roughly 10 to 20 percent by allowing efficient reallocation of scarce water.

Njie et al (2008) also apply benefit-cost analysis to evaluate adaptations to climate change. They investigate increased use of fertilizers and adoption of irrigation for growing cereals in the uplands of The Gambia. Climate change would cause estimated annual damages to cereal production of roughly US$150 million in 2010-2039 and in excess of US$1 billion in 2070-2079. Increased use of fertilizers would yield net benefits that would reduce climate change damages by 10 percent or more. Irrigation, however, is found to yield negative net benefits in the 2010-2039 time frame and mixed results in the more distant future. For cereal production, the high cost of pump irrigation relative to cereal prices make irrigation an inefficient adaptation, at least in the near to medium-term.

Yin et al (2008) apply an analytic hierarchy process, a form of multi-criteria analysis, to evaluate adaptation options for the water sector in the Heihe River basin of northwestern China. Stakeholder meetings and surveys were used to elicit judgments about the effectiveness of different options with respect to four decision criteria and the relative importance of the criteria. The criteria include water use efficiency, economic returns to water use, environmental effects and cost. The results rank intuitional options above engineering measures to increase water supply. Preferred options include economic reforms that would constrain sectors that are large water consumers, water user associations to share information and promote water conservation and transferable water permits for allocating water use.

Lasco et al (2008) perform a tradeoff analysis of effects of adaptations in one sector that spillover and impact other sectors in the Pantabangan-Caranglan watershed of the Philippines. Options are identified and examined for agro-forestry, water resources, and local communities. They find that spillovers are common because the shared water resource creates a high degree of interdependence among people, livelihoods, and biophysical resources located within the watershed. The spillovers include both positive as well as negative externalities. For example, many of the options identified for agro-forestry such as improving water use efficiency and controlling runoff and erosion have beneficial effects on the water sector and on local community institutions. But stricter enforcement of forest protection laws and reforestation to protect water resources can negatively affect incomes and livelihoods of some landowners and cause farmers in informal settlements with insecure land tenure to be forced from their farms. They find that these types of tradeoffs are seldom considered in planning new projects or revising policies, risking negative impacts on others, conflicts among stakeholders in the watershed, and missed opportunities for mutually beneficial actions.

In Mongolia, evaluation of adaptation options for the livestock sector applied a two-tiered screening process with participation from herders, scientific experts and authorities from local, provincial and national offices (Batima et al, 2008). In the first tier, options are screened for satisfying broad criteria for promoting both adaptation and development goals, consistency with government policies, and environmental impacts. Options that pass the first screening are then evaluated against a second tier of six additional criteria. These include capacity to implement, importance of climate as a source of risk, near-term benefits, long-term benefits, cost and barriers. Adaptation strategies that emerge as priorities from this process include measures that generate near-term benefits by improving capabilities for reducing the impacts of drought and hash winters as well as measures that produce long-term benefits by improving and sustaining pasture yields. Some of the specific measures identified as warranting further consideration include improving pastures by reviving the traditional system of seasonal movement of herds; increasing animals' capacity to survive winters by modifying grazing schedules, and increasing use of supplemental feeds; enhancing rural livelihoods by strengthening community institutions to regulate use of pasture and provide local services such as education, training, access to credit and insurance; and research and monitoring to develop and improve forecasting and warning systems.

In the study of dengue fever in the Caribbean, the investigators evaluate adaptation options for cost, effectiveness, social acceptability, environmental friendliness, promotion of local cooperation, and technical/socioeconomic challenges (Taylor et al, 2008). Three options of multiple measures are recommended based on these criteria. The first option would refocus current education, disease surveillance and vector control efforts to be more proactive and to address deficiencies in community involvement. Emphasis would be placed on education that stresses individual responsibility and community benefits of measures to reduce human-vector contact. The second option would combine the above measures with designing, producing and promoting the use of low-cost covered containers for storing rainwater. Discarded and uncovered oil drums are the most commonly used means of capturing and storing water and are ideal breeding sites for mosquitoes. The third option would include all the above plus development and implementation of an early warning system. Early warnings to give advance knowledge of the expected severity of possible disease outbreaks would enable responses to be calibrated to the anticipated threat level. Responses to an alert would include more frequent and extensive vector surveillance and control, stepped up education efforts tailored to the threat level, and more diligent efforts to eliminate breeding sites for mosquitoes.

3.6 Creating an Enabling Environment.

Many studies, including our own, identify numerous options for adapting to existing and changing climate hazards. Some are novel and untested, but many are based on current practices that are amply demonstrated to reduce risks. As we noted earlier, individuals, communities and nations all have a strong self-interest in adapting. Yet many options go unused, or are used much less extensively or intensively than their benefits would seem to warrant.

It is not for lack of options that adaptation lags. It is lack of determination, lack of cooperation and lack of means that impede adaptation. Deliberate and sustained efforts are needed to create an enabling environment for overcoming these obstacles and facilitating the process of adaptation. The efforts need to engage people, stakeholders and authorities from the many different economic sectors and spheres of activity that are affected by climate and should to link across local, provincial, national and international scales.

3.6.1 Creating the determination to adapt

A primary obstacle is a lack of will, or determination, to adapt. This can happen at the individual level (people failing to take simple actions to limit their own exposure to malaria and dengue), the community level (local authorities allowing new development in hazardous locations), the national level (ministries failing to consider climate risks in new programs and not being held accountable), and international (adaptation continuing to receive strong rhetorical support from international environmental and development communities but few resources).

The reasons for lack of will are varied. One is a problem of awareness and understanding. People lack knowledge about, or are uncertain or sceptical about, current climate risks, climate change, options for adaptation and the effectiveness, feasibility and cost of adaptation. Another important reason is that people have other objectives that compete with adaptation for attention, priority and resources. In essence, determination to adapt will not gain acceptance unless people find the evidence compelling that climate risks represent a substantial problem, that addressing the risks warrants priority on par with other objectives, that there are effective, feasible and affordable options and that we know enough to make wise choices.

Greater awareness and knowledge can help to create the determination to adapt. But it is not enough to simply create more knowledge. It needs to get into the hands, or the heads, of people facing decisions about how to allocate scarce resources to achieve their objectives, objectives that include, but are not limited to, reducing risks from climate and other sources. The knowledge needs to be relevant to the decisions being made and understandable to stakeholders and decision makers, who might be residents of hazardous places, resource users and owners, farmers, business operators, community leaders, or government officials. The knowledge also has to be seen as credible and untainted by bias or intent to manipulate.

The different types of knowledge, intended users and functions of knowledge creation, collection, communication, integration and interpretation are generally too many and varied to be done well by a single entity. Networks of knowledge institutions are needed that link between the scientist, practitioner and public; across economic sectors; and from local to national and international actors. In each of the AIACC study areas, knowledge networks are very incomplete and not well coordinated, resulting in substantial gaps in the awareness and understanding of climate hazards, climate change and adaptation among many key stakeholders.

This situation can be improved by strengthening knowledge networks. Investments are needed in scientific research, assessment and capacity in areas that are relevant to understanding climate risks and response options. Expanded efforts are needed to collect knowledge from the experiences and practices of at risk groups, including traditional knowledge. Mechanisms are needed to integrate, interpret and communicate the created and collected knowledge and to assist stakeholders to apply the knowledge in decision-making. Avenues are needed for stakeholders to give feedback about the information received and the information required, as well as to share their knowledge.

Participatory processes that engage stakeholders and attempt to link the different functions and components of knowledge networks can be effective at generating and communicating knowledge that is relevant, understandable and credible. The AIACC project is one example of such a process and similar projects have been initiated and are underway. Ultimately though, the generation and communication of knowledge for supporting adaptation needs to be connected with and embedded in ongoing processes of human development, economic planning, poverty reduction and resource management.

3.6.2 Creating cooperation to adapt

What any one person or organization can do to adapt is very much constrained by what others do or don't do. Cooperation among members of a community can mobilize resources to reduce, hedge and spread risks beyond what individuals acting independently might achieve. Cooperation between local and national authorities can rationalize policies and plans so that they work toward common adaptation goals and not at cross-purposes. Cooperation among stakeholders and authorities from different economic sectors can increase positive spillovers and avoid negative spillovers of their sector-based strategies. And international cooperation can help to assure that actions are based on the best available science, that information about best practices is shared, that financial resources can be pooled and directed toward common goals, and that efforts under different international agreements contribute to adaptation objectives where possible.

Fostering cooperation on adaptation requires leadership within national governments. An environment or science ministry might play a useful role in raising awareness, sharing information about risks and adaptation options, supporting knowledge networks, assessing the implications of new legislation and policies for narrowing or widening the adaptation deficit, and monitoring overall progress on managing climate risks. But environment and science ministries typically lack the standing to marshal resources at the required scale or to compel other ministries to cooperate. The determination to adapt will need to permeate beyond environment and science ministries and be accepted by other ministries as important to their missions and objectives if there is going to be effective cooperation.

The intent of integrating or mainstreaming adaptation with development is to enlist the cooperation of these other ministries and associated stakeholders in making adaptation commonplace in economic and sector-, resource- and livelihood-based planning and programs at national to local scales. Cooperation is not forthcoming when actors and stakeholders in these different spheres of activity view climate change as immaterial to their main objectives and adaptation as a potential new mandate that will divert resources from their priorities. The experience of the AIACC case studies is that stakeholders from varied perspectives often are aware of climate threats to their interests and that, when put in a broad context of managing current climate hazards and not limited to only climate change, are willing to engage with others to assess threat levels and possible responses. Through their participation in an assessment process, many accept, or at least are willing to consider seriously, the need to adapt to narrow the existing adaptation deficit, to limit vulnerability to climate change in the near to medium-term future and to cooperate with others to move toward a climate-proof society.

3.6.3 Creating the means to adapt

Determination and cooperation to adapt are not sufficient by themselves. The means to adapt must also be available. Much of what needs to be done to adapt is at the level of the household and community. But for the most vulnerable households and communities, the means to adapt are in short supply. Often they do not have sufficient resources and know-how to implement measures that would reduce the risks that they face.

Targeting development to highly vulnerable populations to provide expanded and diversified livelihood opportunities and access to services such as clean water, health care, education, and credit can increase the assets of households and bolster their capacity to cope with and adapt to hazards of all types, including climatic hazards. Capacities that are specific to climate adaptation can be increased by providing information, training, technical advice and resources for adopting technologies and practices that can reduce climate driven damages and variability of production and income. Strengthening and supporting community institutions can increase the capacity for collective action to reduce, hedge and spread risks.

3.6.4 Financing adaptation

Financial resources are also an important part of the means to adapt. At the local level, many communities have been resourceful in operating village funds and other mechanisms to provide access to credit for small-scale farmers, enterprise owners and others that have proven useful for helping to finance risk-reducing investments or recover from losses. Private sector finance markets play an important role in financing investments by larger enterprises, for example for large-holder farmers to diversify farm operations, adopt new seed varieties and implement irrigation, and also to provide insurance against losses. Insurance needs particular attention as it is far less prevalent in developing countries than in developed, premium rates, already more than can be afforded by poor and vulnerable communities, are rising, and insurers are withdrawing from many markets where climate risks are high. Private sector innovations in micro-credit and micro-insurance can help to increase the access of the poor to financial resources. National governments also assist with direct financial payments and with subsidized credit and insurance, though in many places financial assistance from national governments to rural and urban poor is diminishing.

At the international level, financial assistance is being provided for adaptation through the Global Environment Facility under the United Nations Framework Convention on Climate Change (UNFCCC) as well as through development assistance from bilateral and multilateral aid agencies. The international funding is acting as a catalyst for raising awareness, building capacity, advancing understanding of risks and response options, and engaging developing country governments in prioritizing and assessing options. Recently, funding is also being made available for experimenting with and implementing selected measures for adapting to climate change.

But the magnitude of the adaptation problem and the likely financial needs in developing countries are far greater than current funding. Compelling arguments have been made that developed countries have a liability to help fund adaptation in developing countries that also exceed current contributions (see, for example, Baer, 2006). International financial assistance for adaptation does appear to be increasing. But it is not clear to what extent these are new resources or reallocations of limited development assistance funds, which is a source of tension for integrating adaptation and development. While the logic for integration is inescapable, there is legitimate concern that this will divert some funds away from critically important development objectives. Ultimately though, financing for adaptation will need to come from multiple sources, including developing country governments and their private sectors, as well as from foreign direct investment, international development assistance, and specialized funds under the UNFCCC and other multilateral sources.

3.7 A Final Word

Climate hazards exact a heavy toll, impacting most strongly on the poor and acting as a drag on development. The toll is rising as climate change widens the gap between our exposures to risks and our efforts to mange them. National governments are increasingly aware of the growing risks and are cooperating in the UNFCCC and other processes to cautiously consider how to respond. But there is not yet widespread determination to adapt.

The determination to adapt can be assisted by increasing recognition that closing the current adaptation deficit provides immediate benefits and is a first step toward adapting to climate change, that feasible, effective and affordable options are available, and that these options do not require certainty about how the climate will change to be effective. But beyond determination, the means to adapt need to be enhanced. Knowledge of climate risks and adaptation response strategies need to be increased. Capacities of at-risk households and community institutions need to be raised and access provided to improved technologies. Climate sensitive natural resources need to be protected and rehabilitated. Financial resources are needed. Most of all, adaptation needs to be integrated with development so that it becomes commonplace in each sector of human activity. The time to act, to make a stitch in time, is now.

3.8 References

Adger, W.N., S. Agrawala, M. Mirza, C. Conde, K. O'Brien, J. Pulhin, R. Pulwarty, B. Smit and K. Takahashi. 2007. 'Assessment of adaptation practices, options, constraints and capacity.' In M. Parry, O. Canziani, J. Palutikof, P.J. van der Linden and C. Hanson (eds), *Climate Change 2007: Impacts, Adaptation and Vulnerability*. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK and New York, USA.

Adejuwon, J.O., T.O Odekunle and M.O. Omotayo. 2008. 'Using seasonal weather forecasts for adapting food production to climate variability and change in Nigeria.' In N. Leary, J. Adejuwon, V. Barros, I. Burton, J. Kulkarni and R. Lasco (eds), *Climate Change and Adaptation*. Earthscan, London, UK.

African Development Bank, Asian Development Bank, Department for International Development, United Kingdom, Directorate-General for Development, European Commission, Federal Ministry for Economic Cooperation and Development, Germany, Ministry of Foreign Affairs – Development Cooperation, The Netherlands, Organization for Economic Cooperation and Development, United Nations Development Programme, United Nations Environment Programme, and The World Bank. 2003. *Poverty and Climate Change, Reducing the Vulnerability of the Poor through Adaptation*. The World Bank, Washington, DC, USA.

Baer, P. 2006. 'Adaptation: who pays whom?' In W.N. Adger, J. Paavola, S. Huq and M.J. Mace (eds), *Fairness in Adaptation to Climate Change*. The MIT Press, Cambridge, USA.

Barros, V. 2008. 'Adaptation to climate trends: lessons from the Argentine experience.' In N. Leary, J. Adejuwon, V. Barros, I. Burton, J. Kulkarni and R. Lasco (eds), *Climate Change and Adaptation*. Earthscan, London, UK.

Batima, P., B. Bat, S. Tserendorj and B. Myagmarjav. 2008. 'Adapting to drought, zud and climate change in Mongolia's rangelands.' In N. Leary, J. Adejuwon, V. Barros, I. Burton, J. Kulkarni and R. Lasco (eds), *Climate Change and Adaptation*. Earthscan, London, UK.

Burton, I. 2004. 'Climate Change and the Adaptation Deficit. In Adam Fenech (ed), *Climate Change: Building the Adaptive Capacity*. Papers from an International Conference on Adaptation Science, Management, and Policy Options. Lijiang, Yunnan, China, May 17 -19 2004. Meteorological Service of Canada, Environment Canada, Toronto.

Burton, I., and M. van Aalst, M. 2004. 'Look Before You Leap: a risk management approach for incorporating climate change adaptation in world bank operations.' Environment Department. Working Paper No. 100 World Bank, Washington D.C., USA.

Callaway, J.M., D.B. Louw, J.C. Nkomo, M.E. Hellmuth and D.A. Sparks. 2008. 'Benefits and costs of adapting water management to climate change and demand growth in the Western Cape of South Africa.' In N. Leary, J. Adejuwon, V. Barros, I. Burton, J. Kulkarni and R. Lasco (eds), *Climate Change and Adaptation*. Earthscan, London, UK.

Chinvanno, S., S. Boulidam, S. Souvannalath, B. Lersupavithnapa, V. Kerdsuk and N. Thuan. 2008. 'Strategies for managing climate risks in the lower Mekong River basin: a place based approach.' In N. Leary, J. Adejuwon, V. Barros, I. Burton, J. Kulkarni and R. Lasco (eds), *Climate Change and Adaptation*. Earthscan, London, UK.

Dabi, D.D., A.O. Nyong, A.A. Adepetu, V. Ihemegbulem and J. Agaye. 2008. 'Past, present and future adaptation by rural households in northern Nigeria.' In N. Leary, J. Adejuwon, V. Barros, I. Burton, J. Kulkarni and R. Lasco (eds), *Climate Change and Adaptation*. Earthscan, London, UK.

Dube, O.P., and M.B.M. Sekhwela. 2008. 'Indigenous knowledge, institutions and practices for coping with variable climate in the Limpopo Basin of Botswana.' In N. Leary, J. Adejuwon, V. Barros, I. Burton, J. Kulkarni and R. Lasco (eds), *Climate Change and Adaptation*. Earthscan, London, UK.

IPCC. 2001. 'Summary for Policy Makers.' In J.T. Houghton, Y. Ding, D.J. Griggs, M. Noguer, P.J. van der Linden, X. Dai, K. Maskell and C.A. Johnson (eds), *Climate Change 2001: The Scientific Basis*. Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK and New York, USA.

IPCC. 2007a. 'Summary for Policy Makers.' In M. Parry, O. Canziani, J. Palutikof, P.J. van der Linden and C. Hanson (eds), *Climate Change 2007: Impacts, Adaptation and Vulnerability*. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK and New York, USA.

IPCC. 2007b. 'Summary for Policy Makers.' In S. Solomon, D. Qin, M. Manning, M. Marquis, K. Averyt, M. Tignor, H. Miller and Z. Chen (eds), *Climate Change 2007: The Physical Science Basis*. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK and New York, USA.

Lasco, R.D., R.V.O. Cruz, J.M. Puhlin and F.B. Puhlin. 2008. 'Spillovers and tradeoffs of adaptation in the Pantabangan-Carrangalan watershed of the Philippines.' In N. Leary, J. Adejuwon, V. Barros, I. Burton, J. Kulkarni and R. Lasco (eds), *Adaptation to Climate Change*. Earthscan, London, UK.

Leary, N. 1999. 'A framework for benefit-cost analysis of adaptation to climate change and climate variability.' *Mitigation and Adaptation Strategies for Global Change* 4:307-318.

Leary, N., C. Conde, J. Kulkarni, A. Nyong and J. Pulhin (eds) 2008. *Climate Change and Vulnerability*. Earthscan, London, UK.

Mataki, M., K. Koshy and V. Nair. 2008. 'Top-down, bottom up: mainstreaming adaptation in Pacific Island townships.' In N. Leary, J. Adejuwon, V. Barros, I. Burton, J. Kulkarni and R. Lasco (eds), *Climate Change and Adaptation*. Earthscan, London, UK.

Martin-Hurtado, R., K. Bolt and K. Hamilton. 2002. *The Environment and the Millennium Development Goals*. The World Bank, Washington, USA.

McCarthy, J., O. Canziani, N. Leary, D. Dokken, and K. White (eds), *Climate Change 2001: Impacts, Adaptation and Vulnerability*, Contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, UK and New York, USA.

McMichael, A., A. Githeko, R. Akhtar, R. Carcavallo, D. Gubler, A. Haines, R.S. Kovats, P. Martens and J. Patz. 2001. 'Human health.' In J. McCarthy, O. Canziani, N. Leary, D. Dokken, and K. White (eds), *Climate Change 2001: Impacts, Adaptation and Vulnerability*, Contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, UK and New York, USA.

Mougou, R., A. Abou-Hadid, A. Iglesias, M. Medany, A. Nafti, R. Chetali, M. Mansour and H. Eid. 2008. 'Adapting dryland and irrigated cereal farming to climate change in Tunisia and Egypt.' In N. Leary, J. Adejuwon, V. Barros, I. Burton, J. Kulkarni and R. Lasco (eds), *Climate Change and Adaptation*. Earthscan, London, UK.

Munich Re. 2005. *Topics GEO – Review on Natural Catastrophes 2005*. Munich Re, Munich, Germany.

Nagy, G.J., M. Bidegain, R.M. Caffera, J.J. Lagomarsino, W. Norbis, A. Ponce and G. Sencion. 2008. 'Fishing strategies for managing climate variability and change in the estuarine front of the Rio de la Plata.' In N. Leary, J. Adejuwon, V. Barros, I. Burton, J. Kulkarni and R. Lasco (eds), *Climate Change and Adaptation*. Earthscan, London, UK.

Njie, M. B.E. Gomez, M.E. Hellmuth, J.M. Callaway, B.P. Jallow and P. Droogers. 2008. 'Making economic sense of adaptation in upland cereal production in The Gambia.' In N. Leary, J. Adejuwon, V. Barros, I. Burton, J. Kulkarni and R. Lasco (eds), *Climate Change and Adaptation*. Earthscan, London, UK.

Osman-Elasha, B., N. Goutbi, E. Spranger-Siegfried, B. Dougherty, A. Hanafi, S. Zakieldeen, A. Sanjak, H. Atti and H.M. Elhassan. 2008. 'Community development and coping with drought in rural Sudan.' In N. Leary, J. Adejuwon, V. Barros, I. Burton, J. Kulkarni and R. Lasco (eds), *Climate Change and Adaptation*. Earthscan, London, UK.

Pelling, M., A. Maskrey, P. Ruiz and L. Hall. 2004. *Reducing Disaster Risk: A Challenge for Development*. United Nations Development Bank, Bureau for Crisis Prevention and Recovery, New York, USA.

Schneider, S.H., S. Semenov, A. Patwardhan, I. Burton, C. Magadza, M. Oppenheimer, A.B. Pittock, A. Rahman, J.B. Smith, A. Suarez, F. Yamin. 2007. 'Assessing key vulnerabilities and the risk from climate change.' In M. Parry, O. Canziani, J. Palutikof, P.J. van der Linden and C. Hanson (eds), *Climate Change 2007: Impacts, Adaptation and Vulnerability*. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK and New York, USA.

Smit, B., O.Pilifosova, I. Burton, B. Challenger, S. Huq, R. Klein, G. Yohe. 2001. 'Adaptation to climate change in the context of sustainable development and equity.' In J. McCarthy, O. Canziani, N. Leary, D. Dokken, and K. White (eds), *Climate Change 2001: Impacts, Adaptation and Vulnerability*, Contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, UK and New York, USA.

Taylor, M.A., A.A. Chen, S. Rawlins, C. Heslop-Thomas, A. Amarakoon, W. Bailey, D. Chadee, S. Huntley, C. Rhoden and R. Stennett. 2008. 'Adapting to dengue risk – what to do?' In N. Leary, J. Adejuwon, V. Barros, I. Burton, J. Kulkarni and R. Lasco (eds), *Climate Change and Adaptation*. Earthscan, London, UK.

Travasso, M.I., G.O. Magrin, W.E. Baethgen, J.P. Castano, G.R. Rodriguez, J.L. Pires, a. Gimenez, G. Cunha, and M. Fernandes. 2008. 'Maize and soybean cultivation in southeastern South America: adapting to climate change.' In N. Leary, J. Adejuwon, V. Barros, I. Burton, J. Kulkarni and R. Lasco (eds), *Climate Change and Adaptation*. Earthscan, London, UK.

von Maltitz, G.P., R.J. Scholes, B. Erasmus and A. Letsoalo. 2008. 'Adapting conservation strategies to climate change in South Africa.' In N. Leary, J. Adejuwon, V. Barros, I. Burton, J. Kulkarni and R. Lasco (eds), *Climate Change and Adaptation*. Earthscan, London, UK.

Wehbe, M., H. Eakin, R. Seiler, M. Vinocur, C. Avila and C. Marutto. 2008. 'Local perspectives on adaptation to climate change: lessons from Mexico and Argentina.' In N. Leary, J. Adejuwon, V. Barros, I. Burton, J. Kulkarni and R. Lasco (eds), *Climate Change and Adaptation*. Earthscan, London, UK.

Yanda, P.Z., Wandiga, S.O., Kangalawe, R.Y.M, Opondo, M., Olago, D., Githeko, A., Downs, T., Kabumbuli, R., Opere, A., Githui, F., Kathuri,J., Olaka, L., Apindi, E., Marshall, M., Ogallo, L., Mugambi, P., Kirumira, E., Nanyunja, R., Baguma, T., Sigalla, S., Achola, P. 2008. 'Climate, malaria and cholera in the Lake Victoria region: adapting to changing risks.' In N. Leary, J. Adejuwon, V. Barros, I. Burton, J. Kulkarni and R. Lasco (eds), *Climate Change and Adaptation*. Earthscan, London, UK.

Yin, Y., Z. Xu and A. Long. 2008. 'Evaluation of adaptation options in the Heihe River Basin of China.' In N. Leary, J. Adejuwon, V. Barros, I. Burton, J. Kulkarni and R. Lasco (eds), *Climate Change and Adaptation*. Earthscan, London, UK.

4 Climate change assessments in Africa

Eleven case studies were undertaken in various regions of Africa with the primary aim of determining vulnerability to climate change impacts and potential adaptation strategies. The distribution of the case studies provided a good coverage of issues pertinent to climate change related impacts across much of the African continent. The studies focused on several diverse topics, which include: biodiversity and conservation in Southern Africa; developing climate change scenarios for Sub-Saharan Africa; agriculture, water resources and food security in North and East Africa; assessing climate change scenarios for West Africa; agriculture in Sub-Saharan West Africa; integrated assessment of various economic sectors in the Miombo region; water resources and food in semi-arid Eastern Botswana; water resources and agriculture in South Africa and the Gambia; agriculture and water resources in North Africa; human health in the Lake Victoria region; and water resource availability in the Sahel region of West Africa. Summary information on each of the individual case studies is provided below.

* Details about the scientific literature referenced in the project summaries below are available in the final project reports available at: http://www.aiaccproject.org/Final Reports/final_reports.html

4.1 Impacts and Adaptations to Climate Change by the Biodiversity Sector in Southern Africa (AF04)

Summary Information

Country: South Africa
Principal Investigator: Dr Robert (Bob) J. Scholes
Administering Institution: CSIR, Division of Water, Environment and Forest Technology (Environmentek), Pretoria, South Africa

Research problem and objectives

The South African country studies on vulnerability to climate change (Kiker, 2000) identified biodiversity as one of the sectors particularly at risk from the negative impacts of climate change. This led to a concern among researchers and conservation officials about the need for adapting to these impacts. The climate change research community in South Africa therefore took advantage of the AIACC funding opportunity to address this issue beginning with the development of a conceptual framework within which to consider the adaptation of biodiversity to climate change; and aiming to develop, test, and transfer a set of tools that could be used by officials dealing with biodiversity conservation to apply in the analysis of response options.

The objectives of this project were to:

1. Develop and test methods to project the dynamic response of biodiversity to climatic change.
2. Develop planning tools for the prioritization of conservation planning in a non-static environment, largely due to the result of climate and land use changes.
3. Evaluate, in terms of economic costs and effectiveness, adaptation options for biodiversity conservation.
4. Collate, assess, summarize and publicize the information relating to potential impacts on South African biodiversity from the combined effects of climate and land use change in the 21st century.
5. Advance the field of dynamic biodiversity conservation and develop capacity in the research and management communities to address climate change issues in a proactive and effective way.

Approach

In comparison to prior work in South Africa this study viewed climate change as a transient (continuous) phenomenon, rather than as an equilibrium (step change) phenomenon. This required the development of dynamic niche modeling tools and approaches to conservation estate optimization for non-stable climates. Secondly, non-climate 'global change' factors, which influence the behavior of organisms, were introduced into the analysis.

Thirdly this study moved beyond very simplistic approaches to niche envelope modeling and to more sophisticated ones that involved more robust statistical approaches and multiple (but independent) dimensions, including niche dimensions such as substrate and the presence of synergistic species. Approaches to modeling the functional attributes of biodiversity under climate change were also developed, rather than purely compositional aspects for example questions like: what will the population sizes and productivities be in the future?

Fourthly biodiversity conservation was viewed as a continuum from strict protection in formal protected areas, through off-reserve protection on private lands used to varying degrees for other purposes, and right through to ex situ protection in zoos, gardens or even gene banks. Conservation strategies can thus consist of a portfolio of actions with different attributes, a range of degrees of success and risks, and the optimization lies in the mix of the portfolio.

Finally adaptation strategies were couched in an economic framework in order to estimate the costs of the various options available.

Three case studies were used to develop and test tools and methodologies for better understanding the response of species and ecosystems to the predicted impacts of climate change. Barring evolution, biological organisms effectively have four possible response options to changes in climate, and based on this organisms are grouped into the following functional groups (see Figure 4.1):

1. *Persisters:* Species that have the tolerance for the new climate.
2. *Obligatory dispersers*: Species that must move to new areas that maintain their current climate envelope in the future.
3. *Expanders*: Species that will find new habitats in the new climates i.e. they can expand into new climatic envelopes not previously available.
4. *No hopers:* Species that are unable to find any suitable climatic envelopes in the future climate and will become extinct.

Based on the response options available to individual species, the following potential adaptation options were identified (see Figure 4.1):

- Do nothing (i.e. maintain the current conservation strategy).
- Reconfiguration of reserve system.
- Matrix management. i.e. managing the biodiversity in areas outside of reserves.
- Translocation of species in to new habitats.
- Ex-situ conservation.

An economic analysis of the costs of different conservation options was undertaken based on the results from the Fynbos case study.

Scientific findings

Rapid advances in individual species dispersion modeling techniques between conceptualization of the project, and actual implementation, allowed the development of methodologies based on individual species response, rather than habitat level responses. A grid based approach was developed that made far simpler assumptions on dispersal distances in any time period. A time slice methodology was developed to predict individual species' dispersal response to predicted climate change. The data rich Proteaceae distribution data was used to test the model for the Fynbos biome of the Western Cape. The model was able to identify important distribution corridors that would allow obligatory disperser species to track climate change.

Though most of the Protea species were projected to persist in the predicted climate of 2050, about 11 percent of species had no future habitat and 6 percent would need to move to new locations. Results from this study were used to review strategic conservation strategies for the region. In addition data from this case study was used to investigate the use of economic models to better understand the cost effectiveness of various adaptation options, including expanding the reserve network, promoting conservation outside of the reserve network (matrix management), facilitated dispersal, ex-situ preservation or doing nothing.

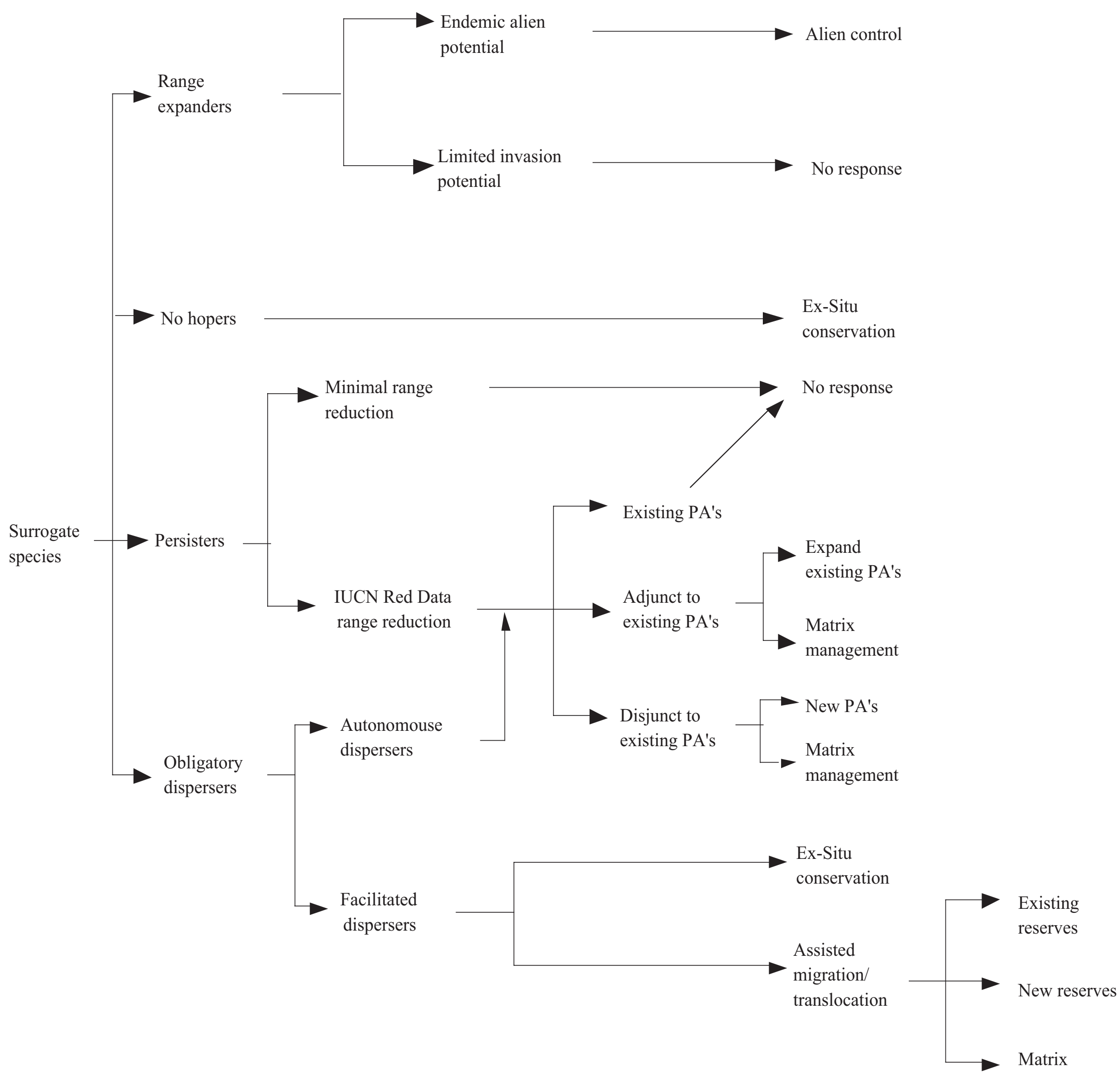


Figure 4.1: A decision tree for selecting adaptation strategies for different surrogate species based on their response to climate change (Adapted from Midgley et al in prep).

Models to understand the likely extinction of individual animal species, based on the impacts of climate change on habitat structure and food plants were applied to two karoo species, the highly endangered riverine rabbit (Bunolagus monticularis) and the padloper tortoise (Homopus singnatus). The climate change scenarios investigated were found to increase the likelihood of extinction for the riverine rabbit, whilst the padloper tortoise was expected to persist, which would facilitate adaptation.

Modeling approaches based on empirical equations for predicting the key functional properties of savannas (tree cover, fire frequency, grass and browse production and carrying capacity for major guilds of herbivores and carnivores) were developed for the northeastern lowveld savanna. The model considered both the impacts of temperature and rainfall, as well as changes in CO_2 on relative competitive advantage of grasses and trees. This approach predicted a slight increase in woodiness in the coming century. Elephant density and fire were found to be important variables controlling vegetation dynamics.

In determining the economic costs of adaptation options it was assumed that benefits would be measured in terms of the number of species that would be conserved using different adaptation strategies instead of attempting to derive a total economic value of saved species. Total economic valuation was discarded because a) there was no objective way to value non-use values, b) many non-consumptive use values cannot be objectively distributed between different biota in any specific habitat and c) solutions based purely on current human values were not desired.

The economic modeling found that the cost of expanding the conservation network was inversely related to the size of conservation areas. In most circumstances managing the biodiversity in farmlands outside of conservation area i.e. matrix management, was found to be a more economically viable option than expansion of the reserve network. The exception to this is when land has the potential for high value crops such as grapes. Under these circumstances placing the land in a reserve may be more economically viable provided that the area is relatively large. In all other situations a contractual relationship where the farmer is paid not to farm and is compensated at the opportunity cost of lost production is a more economically viable option than establishing a formal reserve. Lower cost options that encourage biodiversity-friendly farming are also available for less critical areas.

Ex-situ conservation would be required for species that have no suitable habitats in the future. The costs of ex-situ conservation cannot be directly compared with conventional conservation since it has different objectives. Due to the uncertainty of climate change scenarios and poor understanding of individual species response, ex-situ conservation must be considered as a safety strategy to protect all species from extinction.

Overall, strategies for individual species would differ based on individual adaptive capacities. It is possible to re-configure protected areas either through reserves or matrix management to provide greater protection for biodiversity given the changes in climate. The necessity for intervention would remain for specific species that will either have no available dispersal corridors and which will need assistance in migration, or which have no future habitat (in the 50 to 100 year time frame) and will need ex-situ conservation until the impacts of climate change reverse. Simple strategies such as the protection of potential migratory corridors along environmental gradients are confirmed.

Capacity building outcomes and remaining needs

The project helped to build human capacity in research on issues pertaining to climate change and biodiversity vulnerability and adaptation via the direct involvement of researchers in the project. A supplementary AIACC grant also helped to support a training course for researchers from ten SADC counties and a number of South African institutions. Parts of the research findings from the project have been incorporated into a postgraduate training syllabus. A web based training module housed at the University of the Western Cape is available as a self learning module and is also used as a component of the postgraduate training module (http://planet.uwc.ac.za/nisl/AIACC).

National communications, science-policy linkages and stakeholder engagement

A memorandum, based on AIACC activities in project AF04, formed the basis for a briefing paper for the national team's UNFCCC COP9 negotiations. This memo indirectly precipitated the increase in governmental concern about climate change threats to South Africa, and contributed to informing its negotiating position. Two core research team members have been actively involved in representing South Africa on IPCC working group panels i.e. Dr Bob Scholes: IPCC working group three on agriculture and Dr Guy Midgley: IPCC working group two on ecosystems. Dr Scholes and Dr Midgley are also a part of the South African negotiating team for UNFCCC meetings.

Policy implications and future directions

National issues

1. There is a need to incorporate planning for climate change in biodiversity conservation strategies
2. The old paradigm that species should only be located in areas where they historically occurred might not apply under future conditions
3. The protected area system could be configured to improve protection against climate change, including providing for species movement.
4. Conservation authorities need to maximize off-reserve conservation, which is both cost effective and provides more spatial options, given the constraints presented by current economic and land use realities.

Regional issues

1. Transfrontier movement of biodiversity will be important given climate change. As a result, regional strategic conservation planning needs to consider park configuration to best protect against the impacts of climate change.
2. Regional capacity building, especially in SADC countries other than South Africa is needed to develop sufficient capacity to deal with adaptations to climate change.

Global issues

1. The negative impacts of anthropogenic climate change for biodiversity, in both utilitarian and intrinsic terms, are quite high, and need to be better understood and communicated.

Future directions and research needs

1. Determination of impacts of biodiversity loss on income and livelihood strategies
2. Progression from case studies to national strategic assessment
3. Assessment of sub-regional level of threat
4. Detailed studies on threatened genera
5. Capacity building in other SADC countries

4.2 High Resolution Regional Climate Change Scenarios for Sub-Saharan Africa (AF 07)

Summary Information

Country: Ghana, Nigeria, Senegal, South Africa, Zambia and Zimbabwe
Principal Investigator: Dr. Bruce Hewitson
Administering Institution: University of Cape Town, South Africa.

Research problem and objectives

Africa encompasses some of the worlds' regions most vulnerable to climate change. This is unfortunately compounded by a poor understanding of the nature of the vulnerability due to issues such as, a small under-resourced scientific community with minimal access to regionalized climate change scenarios; limited methodological experience and skill in regional modeling; and therefore an under-researched regional climate system. This lack of scientific understanding tends to increase the potential severity of climate change impacts and limits response options. As such, the impacts research community has little to draw on beyond raw General Circulation Model (GCM) outputs produced predominantly by the western nations in the Northern Hemisphere, with all the attendant problems of using GCM grid cell data. This situation in itself represents a significant additional vulnerability for the region. This project therefore attempts to address these concerns with the objectives of:

- Capacity development of African scientists to research aspects of the climate system pertinent to African needs;
- Encouraging the development of a regional climate model-literate community within Africa;
- Development of new statistical approaches to generating climate change scenarios at time and space scales appropriate for regional impacts research;
- Development of regional climate model-based projections of climate change and assessment of their strengths and weaknesses;
- Dissemination of climate change information with appropriate guidance to impacts researchers.

Approach

The approach of this project has largely been dictated by the objectives stated above. The complexity of the climate system and the complex, computing capacity intensive and data intensive nature of climate models has historically resulted in such research being confined to western developed nations with developing countries forced to rely upon information generated elsewhere. However advances in computing technology along with the availability of more economical computing systems has now made it possible to run climate models, at a low cost, within Africa. This project takes the view that an Africa-wide climate model-literate community, that can apply its knowledge to African problems, is essential for addressing Africa's needs. It also recognizes that expertise in climate modeling often lies outside Africa and the interaction of African researchers with their peers overseas is important.

The African climate is tough on computer components and the acquisition of spares is often difficult. In this situation this project has attempted to promote (by supplying both hardware and expertise) the use of climate models at five sites in Africa: Ghana, Nigeria, Senegal, Zambia and Zimbabwe. It has helped to develop further capacity (both infrastructure and intellectual) at the project home base in Cape Town by building on the existing capacity. As a result new techniques for scenario development have been generated and regional climate models can now be applied to the under-researched aspects of the local climate system and scenario development.

Scientific findings

Besides increasing the capacity to conduct fundamental climate research within Africa, the project produced important scientific results, including the development of a new empirical downscaling technique, which demonstrated convergence between projections from a suite of GCMs and the detection of trends in the regional climate dynamics, which are also projected in the GCM future projections. The following summarizes some of the most pertinent findings of this project:

1. Global Climate Models (GCMs) vary widely in their representation of African climate, both in terms of parameterized variables (e.g. rainfall) and regional dynamics
2. Regional Climate Models (RCMs) also vary widely in their simulations of local climate. One particularly important aspect in this regard can be the choice of convective parameterization in the model.
3. The observational network for validating these models is sparse over most parts of Africa and non-existing in certain regions e.g. Democratic Republic of Congo and Angola.
4. Aspects of the land-surface are important to correctly simulate the climate of Africa e.g. soil moisture and vegetation. These may be important components of future change that are not currently addressed to a large degree.
5. There have been consistent trends in climate over southern Africa during the last three decades. Often these trends are easier to observe in statistics of daily climate e.g. rain days. However it is still unclear whether these trends are due to climate change or periodic changes in the circulation of the southern hemisphere.
6. Statistical downscaling of future climate can go some way towards reducing the uncertainty found when using the direct output from multiple GCMs.
7. RCM projections of future climate will likely be influenced by the configuration and hydrological cycle of the RCM.

From the development and analysis of scenarios some consistent projected changes have become apparent, which include: i) a drying towards the west of southern Africa during summer, consistent with an increase in the frequency of extensive high pressure systems over the Atlantic; ii) an increase in rainfall over East Africa, iii) increases in rainfall over eastern southern Africa during late summer; iv) 1-5°C increases in temperature over much of southern Africa. It should be noted that these generalized projections are highly time- and space-dependent.

Capacity building outcomes and remaining needs

Efforts to install climate modeling facilities within Africa have met with varying degrees of success. Of the five sites under study, three have contributed directly to this report and research on aspects of their local climate has continued despite hardware failures and often, slow internet access. Results generated in Zambia and the experience of the local researcher there have led to investigations of the RCMs response over southern Africa, an important aspect of this project. The modeling undertaken in Senegal is also expected to inform the generation of RCM scenarios in that region. Overall the capacity building aspects of this project have been successful with perhaps the most important aspect being the building of a model-literate community within Africa. In the areas of successful project implementation there have often been additional spin offs, such as student learning and projects.

The following is a list of some of the major factors that have influenced the installation of climate-modeling facilities within Africa:

1. Internet access - when slow this restricts information flow both in terms of data necessary to run a climate model and in terms of interactions with peers in other countries. Additionally it may prevent remote access and fixing of software problems by technicians at remote sites;
2. Access to spares - particularly hard disks in the event of hardware failure and the scarcity of funds to buy such spares;
3. Availability of researchers - many university teachers and researchers within Africa have high workloads and can only afford the luxury of research in their own spare time;
4. Local technical knowledge - to fix problems either with hardware or software, in particular the operating system;
5. Data storage capacity and backups – this is important given the large volumes of data generated by such activities and the propensity for hardware failure.

National communications, science-policy linkages and stakeholder engagement

This project has produced some of the highest resolution available in climate change scenarios for the African continent. The statistical downscaling scenarios are now available and are in the process of being incorporated into a number of projects within South Africa. The RCM scenarios are beginning to come online and are expected to complement those from the statistical downscaling. These scenarios have informed adaptation strategies formulated by the municipalities of Durban and Cape Town (South Africa). Data supplied via this project has also been used to assess the impacts of climate change on river basins and hydroelectric power generation within Zambia and the southern African region. Data is also being utilized for other projects in South Africa that seek to judge the impact of climate change on agriculture and water resources in major river catchments such as the Tugela in KwaZulu-Natal. Other possibilities currently under discussion include the effect of climate change on the Okavango delta in Botswana. Efforts are on to make the scenarios available via the internet, which will enable free access in the future. Interactions with stakeholders and policy makers initiated via the project are expected to increase as the scenarios developed by this project become available and a wider group of potential users become aware of their existence.

Policy implications and future directions

The AIACC program has helped to create a research base in the area of climate change scenario development and future climate modeling for the African continent, which could serve as an important resource to inform policy in the area of climate change vulnerability and adaptation. It is therefore imperative that the momentum achieved through the AIACC program and other complementary activities be maintained in the future and a priority policy need is for the long term sustainability of the distributed and collaborative scientific capacity, along with the related infrastructural resources. Of critical importance is the support of the junior, or emerging, scientists such that they are not subsumed into the significant overheads of African institutionalized research structures. Following this need, perhaps of secondary importance is the need to foster communication, specifically between the science team engaged with scenario development and the impacts research community, thereby facilitating the dissemination of tailored scenario products and climate system understanding.

Overriding all the work to date and the challenges of future research, is the critical need to access continued support to maintain momentum, otherwise the developments of this project, while valuable for the immediate needs of the impacts community, will nonetheless be relegated to (merely) another finite lifetime project arising out of the intervention of foreign funding. However, the fact that the project has been African designed and African led is an important evolution in the application of foreign funding. Much has been achieved, and it is anticipated that this will catalyze appropriate development toward achieving the goal of a sustainable critical mass of climate change researchers within the continent.

4.3 Environmental Strategies to Increase Human Resilience to Climate Change: Lessons for North and East Africa (AF 14)

Summary Information

Country: Sudan
Principal Investigator: Balgis Osman-Elasha
Administering Institution: Higher Council for Environment & Natural Resources (HCENR), Sudan

Research problem and objectives

Despite the remaining uncertainty surrounding the magnitude, pace and character of future climate change, there is an urgent need for capacity building in Africa to cope with and adapt to climate impacts. Throughout Africa, there are activities that achieve resilience-building goals, enabling communities to cope more effectively with shocks and stress, including climate impacts. In light of two key observations – the uncertainty around climate projections and the tenuous and at worst deteriorating state of human development in Africa – there is a need to understand and build on these activities. While advancing mitigation, the global community as well as individual African states must overcome the bureaucratic distinction between adaptation to current climate impacts and future climate change and must support broad-based resilience building, uniting the development and adaptation communities in the process. In essence, adaptation cannot be effectively undertaken separate from poverty alleviation and sustainable development activities in general, just as poverty alleviation efforts will be short-lived if undertaken without consideration of climate change and improved coping needs.

This project is motivated by the above observations, and by the understanding that limited information exists for adaptation decision making at all the levels (international, regional and national) as well as for African decision-makers who might wish to pursue efforts that achieve both these goals. Poverty alleviation and adaptation are not synonymous; instead, they overlap, sometimes indistinguishably in ground-level activities. In light of this and in anticipation of growing demand for information on such activities, the objective of this project has been to demonstrate a method for generating information on effective resilience-building activities, and to raise the profile of such activities within the climate adaptation and broader development communities.

In Sudan, where drought is a current threat and will continue to be in the foreseeable future – potentially worsening under climate change – activities to improve community and household capacity to cope with drought are of particular value. Certain environmental management strategies (sustainable development activities) in Sudan – whether approached from a poverty alleviation or natural resource management perspective – have been quite effective in this regard. This project explored three examples of such experiences, documenting both, the lessons they had to offer and, equally important, an approach to extracting those lessons and to better understand how to support community coping capacity.

Approach

This study was based on the following premises:

- As a primary goal adaptation must strive to increasing the capacity of the most vulnerable groups to cope with today's climate-related impacts
- For this purpose, small-scale, community-level strategies, that increase the resilience and adaptive capacity of the most vulnerable groups while accomplishing added social and environmental goals (e.g., slowing desertification) must be considered alongside the large-scale, technical/structural approaches that could potentially dominate adaptation planning. Decision-makers must be adequately informed about such small-scale strategies.
- Such methods have been developed under the sustainable livelihoods, natural resource management and disaster risk management frameworks and could also meet climate change adaptation needs.
- Finally such strategies could help diversify and strengthen national adaptation plans of developing countries, and development efforts in general.

This project aimed to identify, explore and discuss such strategies in order to make them accessible, readily understandable and useable to the policy-making process. The project research consisted of three interlinked processes – the empirical, in which background information is gathered and organized; the analytical, in which case studies are carried out; and the participatory, in which community input, validation and guidance is sought. Case studies served as the primary research tool for this purpose and used the sustainable livelihoods framework to enable researchers to measure resilience at the local level to climate-related impacts. With this approach, the following research scope was established:

- Three case studies in different arid regions of Sudan, investigating current and recent historical experience, were undertaken with a focus on the period between 1980s to the present. These were conducted by commissioned researchers, by means of desk-based and field research over a six-month period.
- Each case study focused on a single community or cluster of communities within an ecological/agricultural system as its unit of research.
- Each case study explored examples where "local" knowledge (e.g., traditional, indigenous, autonomous, informal) and/or "external" knowledge (e.g., formal, technical, directed) have been applied within a target community (ies), generally in the form of sustainable livelihoods (SL) or natural resource management (NRM) measures, to enable the community to cope with or adapt to climate-related stress. Each community's resilience to climate extremes, before and after project activities was compared.
- Finally, case studies were selected based in part on advance knowledge that the case represents a successful example of community-based measures reducing community vulnerability to drought. The project accepted, based on initial scoping activities and direct community consultation, that a set of measures was basically effective, and focused instead on (1) the extent to and manner in which these measures increased local resilience to drought impacts, and (2) why? (i.e. because of what local, national, regional policies and conditions?).

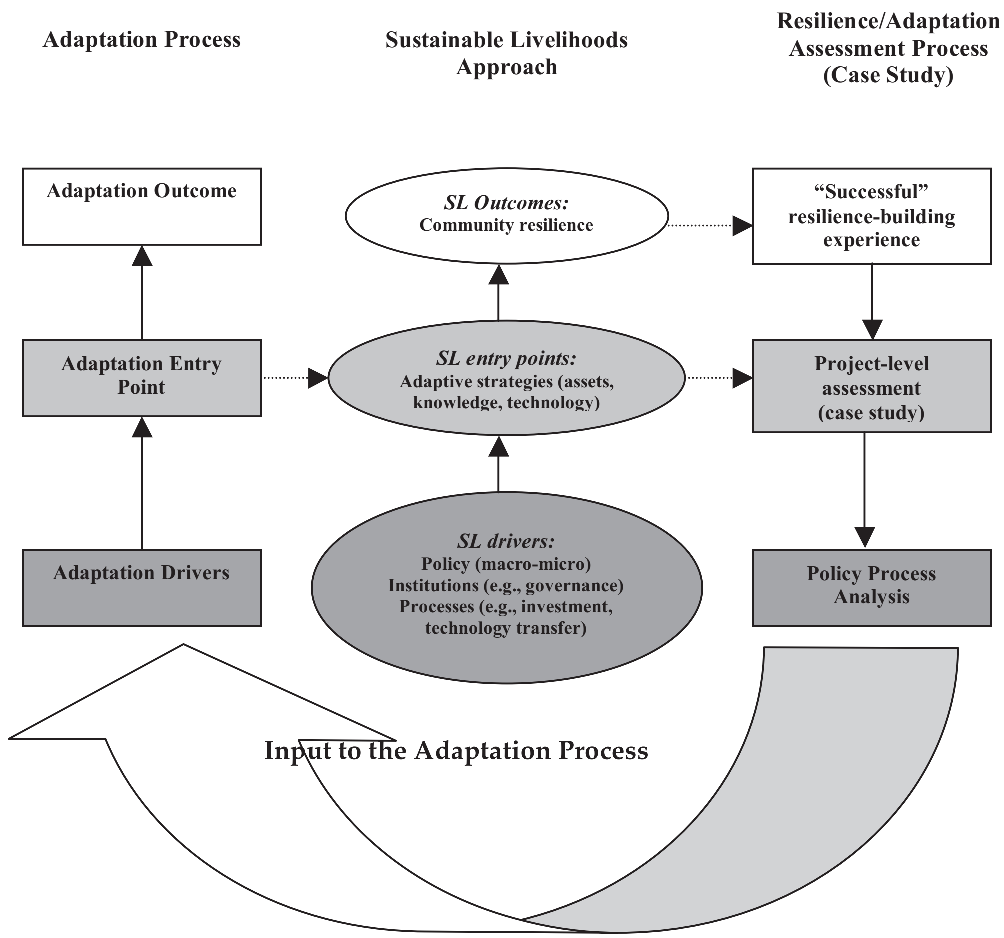


Figure 4.2: Adapted version of the UNDP approach to sustainable livelihoods

Building from this framework, the case studies themselves sought to:

- Generate informative background material on each community's unique context, vulnerabilities, assets, coping strategies, etc.;
- Employ methods to measure individual community resilience to climate-related impacts, with and without the project measures;
- Employ policy analysis techniques to explore the relationship between community resilience-building activities and micro-, meso- and macro-scale policies, institutions and processes; and
- From the above, draw lessons for increasing community climate resilience that can be applied to adaptation and related processes.

This study did not develop climate scenarios but instead relied upon historic climate records and existing climate scenarios and used current climate as a proxy for climate change. Vulnerability assessment was not specifically undertaken instead, the project focused on areas of known, historic drought vulnerability, attempting to assess vulnerability as perceived by the local communities from their description of their livelihood condition before the intervention and considered promising and contextually appropriate adaptation options. Furthermore, in-depth policy and institutional analysis was not undertaken, which could be an area for future follow-up research.

Scientific findings

The exploration of the three case studies revealed several broad themes, which echo basic principles of sustainable livelihoods and sustainable rural development. This was not unexpected, since the case studies deliberately explored projects that had experienced success in achieving rural development goals. It is important to reiterate that households and communities articulated, through consultations and interviews, what it is that enables them to cope with climate impacts, and then expressed how those indicators changed following the establishment of project activities. Thus, while the observations generated are fairly commonplace in development circles, in this study they have been assessed specifically through the climate change lens, offering lessons for climate coping, as opposed to coping and resilience in general. In this light, valuable observations across case studies include the following:

- Strategies and measures for the sustainable management of natural resources can support broad improvements in livelihood security and household and community capacity to cope with climate impacts. Specific examples observed include both autonomous natural resource management (NRM) efforts, such as the water resource management systems developed in Darfur state, and those stimulated by NGO or other external, supportive organizations, such as the rangelands rehabilitation program implemented in Bara Province, Kordofan state.
- The capacity to finance not only coping mechanisms but also livelihood diversification activities that can pre-emptively lower climate vulnerability is key. In this sense, savings in liquid or like form (e.g., livestock, food stores) are critical, as is access to micro-credit to temporarily substitute for liquid assets.
- Access to basic, low-tech materials for the development and improvement of local infrastructure is also important e.g. materials and support provided for building food storage facilities or for maintaining water harvesting systems were considered important by vulnerable communities. Moreover, these communities assigned great value to basic tools and inputs such as improved seeds and access to farm and earth-moving equipment.
- A widely held understanding – that human skills are critical to coping and resilience – serves to emphasize the inter-related nature of many of the indicators of coping capacity explored via the case studies. Specifically, many of the things that enabled improved coping capacity within households and communities also required improved human capacity – from animal health care skills, to mechanical skills for the maintenance of machinery, to soil management skills, to community organizational capabilities. As the breadth and depth of human skills and capacity grows, so grows resilience and adaptive capacity.
- Finally, the case study observations serve to buttress the broadly held view that social capital is one of the most important determinants of resilience to shocks, in this case, climate-related shocks and stress. Family and informal social networks, community groups, self-help groups, effective local decision-making bodies and institutions were each identified as important resources for building and preserving the capacity to cope with climate impacts.

While the more detailed observations outlined in the body of the report point to specific measures that can be taken, it is important to note that the tools used to assess the impact and effectiveness of development projects can be successfully applied to the assessment of climate change adaptation options.

Capacity building outcomes and remaining needs

The methods used in this project represent one approach for assessing the impact of community-based activities. Others exist and can be applied for the same purpose. More important perhaps than the specific method applied, though, is the capacity among potential users to effectively apply the methods. The teams charged with assessing climate change vulnerability within their countries and determining adaptation options (e.g., for National Communications or the NAPAs) tend to be composed primarily of physical, rather than social scientists, and as a result are less likely to have strong inherent skills in the type of community-based assessment suggested here. Thus, if these types of methods are considered valuable, a strong need exists for building team capacity to apply them. The project is in the process of developing material for this type of training to be offered and/or supported in Sudan and North and East Africa.

Clearly, though, capacity building needs exist beyond the climate change community. If a key challenge is the integration of climate adaptation with broader sustainable development processes, then awareness and capacity among key actors in the broader arena must be increased. While it is beyond the purview of this project to undertake such capacity building, it will nonetheless offer material, which can be used by others to explore these issues and to build understanding of adaptation and human development links.

National Communications, science-policy linkages and stakeholder engagement

This project was initially motivated in part by the limitations of the First National Communications process, and was designed to produce outputs useful to subsequent analyses. Thus, an immediate and promising entry point is for the project methods and findings to feed into the design of the Sudan Second National Communications (SNC), and ultimately, into the recommendations for adaptation that emerge from the SNC. The project has already influenced Sudan's NAPA process to some extent, with, for example, the NAPA review of successful coping experiences including the project case studies and others like them. As the acceptance of and capacity for stakeholder engagement among climate change teams builds, the process outlined here can meet local community engagement needs in a highly constructive, mutually informative way. Ideally, in the next full round of Second National Communications, a number of developing countries will apply methods demonstrated here to the task of assessing adaptation options for highly vulnerable people. In addition, this study could help to influence Sudan's key decision-makers toward adopting practical ways of mainstreaming climate adaptation with broader development policies e.g., through more sustainable rangeland management policies, or through national water resource policies that actively support localized water management, etc.

Policy implications and future directions

This project is intended, first and foremost, to build the resilience and coping capacity of communities in Sudan vulnerable to climate impacts, through improved policies and effectively targeted programs and projects. Ideally, some of the knowledge and experience acquired through this project will be integrated into Sudan's emerging adaptation efforts and used as a basis for mainstreaming adaptation within development policy more generally. If the outputs – either the methods or the lessons – can be taken up and applied elsewhere, they have the potential to help improve the effectiveness of adaptation planning efforts as well as future development work. Ultimately, efforts such as this should be supported, even if informally, by the UNFCCC; however, this will require addressing the currently imposed distinction between adaptations to current versus future climate. At present, only the latter is supported within the UNFCCC, though a broader definition of adaptation may be required given the ambiguous distinction between the two on the ground.

Moreover, the work laid out in this report is aimed at enhancing Sudan's contribution in regional efforts on adaptation to global climate change, in particular regional efforts in the African Sahelian Region and North Africa. The focus will be on community-level measures and environmental management strategies that improve the overall resilience of the physical and human environment to adverse climatic conditions.

4.4 Assessing Global and Regional Climate Change Scenarios for West Africa (AF20)

Summary Information

Country: West African countries
Principal Investigator: Dr. Amadou T. Gaye
Administering Institution: University Cheikh Anta Diop Dakar, Dakar, Senegal

Research problem and objectives

With the observed tendency towards a warmer world and rainfall variability from intra-seasonal to decadal timescales, West Africa will experience severe impacts of climate change on food production, water resources, and human health. Since the late 1960's, a significant trend towards lower rainfall has occurred in West Africa. The consequences on national and regional scales have been negative. In the future, these changes are expected to continue and will be accompanied by a warming trend, a rise in sea level, and an increased frequency of extreme weather events. Within West Africa, important gradients in vegetation, temperature, and precipitation; large numbers of meso-scale convective systems (e.g., squall lines, MCCs) that are responsible for most of the regions rainfall; and regional orographic zones (e.g., Guinea highlands, Jos Plateau) and lakes (e.g., Lake Chad) are not represented adequately in global climate models (GCMs). Therefore, regional climate models will be required to understand climate change vulnerability at a regional scale. This project seeks to address this deficiency by assessing climate change scenarios using global and regional climate model simulations for use in impact studies within tropical Africa.

Approach

Project activities included analysis of observed and simulated present-day summer climate in West Africa. Global and regional climate models were used to produce the simulated data for analysis. The National Center for Atmospheric Research (NCAR) CSM model is a coupled system with four components (atmosphere, ocean, land, and sea-ice) while The NCAR CCM3 is an atmospheric (i.e., uncoupled) version of the NCAR climate modeling system. PRECIS is the Hadley Centre's state of the art regional climate model. This project evaluated the performance of each model in reproducing observed trends.

Simulations were made for the time period 1 January 1960 to 30 December 1990. The boundary conditions were provided by a thirty-year integration of the Hadley Center global model using observed time series of sea surface temperature and sea ice. The observed evolution of anthropogenic and natural emissions over the integration period was used to provide relevant atmospheric composition. The evolution and impact of sulfur dioxide and natural emissions on atmospheric composition was simulated within a sulfur cycle component of the models. Model simulations were compared to observations and analysis of observations of present-day climate to examine model biases and capabilities in the reproduction of climatic features. The possibility of using the coupled model (CSM) to drive regional climate models at their own boundaries was also examined.

Next, this project investigated West African mean climate conditions as simulated by the Regional Climate Model RegCM3, developed by NCAR and the Pennsylvania State University (PSU). The RegCM3, an augmented version of the NCAR-PSU Mesoscale Model MM4, is based on the concept of one-way nesting and is employed to drive the coarse mesh lateral boundary conditions of global datasets and to produce fine mesh output data. RegCM3 simulations were driven at lateral and boundary conditions by NCEP reanalysis and ECHAM global climate model outputs. The domain used in this study encompasses the whole of West Africa and the adjacent Atlantic Ocean. Using the Grell scheme and the Fritch and Chapell closure assumption, RegCM3, nested into the ECHAM5, was integrated from 1992 to 1998 with a resolution of 40km. Results of the simulation were compared to CRU observation data.

Scientific findings

This project's analysis provided greater evidence of regional climate change. Present-day station rainfall and temperature data analysis provided further evidence of warming and drought in West Africa. In model comparisons, significant improvement in the simulation of regional conditions was noted with the CSM model. The regional circulation features were better in the coupled model likely because land, atmosphere, ocean, and sea ice interactions were represented. For these reasons, the CSM was proposed as a possible candidate to drive regional climate models over West Africa.

Interpretation of CSM-simulated future climate provided some evidence that the Sahel region of West Africa is expected to be warmer and wetter in the late 21st century. The greatest warming is expected in the Sahara desert, the least warming in the Sahelian zone. More warming is also expected during the Northern Hemisphere winter and autumn – findings that contrast current observed trends showing warming during summer. Sahelian precipitation is expected to be greatest in August, September, and October. Late withdrawal of the West African monsoon is therefore probable in the latter part of the 21st century. Over coastal regions of West Africa, an increase in August rainfall associated with a decrease in June and September rainfall is a probable change noted in the simulated, late 21st century monsoon.

Simulations using the regional PRECIS model captured the general features of the observed monsoon circulation (i.e., southwesterly winds in the lower troposphere, mid- and upper level jets); however, the monsoon circulation was too strong in the model's atmosphere as has been noted over other tropical regions. There was also a surface temperature cold bias in the model over much of the Sahel throughout the year, except in winter. This bias is most likely related to model deficiencies in cloud/solar radiation interactions. The model performed relatively well at simulating the annual cycle and sub-decadal variability of temperature and precipitation over the region. It correctly simulated the dry epochs of the 1970's and 1980's in the Sahel. A systematic early start of the rains occurred in the model atmosphere where rains began one to two months before observed onset time. The model did perform well in simulating the peak and withdrawal period of rainfall. The interannual variability of rainfall was not well captured in the Sahel, but the reverse was the case over the Gulf of Guinea where the model performed relatively better.

The RegCM3 model reproduced quite well the annual cycle over West Africa. It overestimated the precipitation rates south of Cameroon during March, April, and May, however, which can be attributed to boundary effects. Also, the model had some problems in representing orographic precipitation in June, July, and August. Basically, the annual cycle of temperature was identified, but the model showed cold biases in the Guinea regions and warm biases in the northern regions. Zonal wind was simulated as well and compared to the NCEP reanalysis. The position of the AEJ and the TEJ are found, but their strengths were overestimated and underestimated, respectively. These biases may result from the ECHAM data, which, contrary to the NCEP data, are not produced by data assimilation and are the outputs of ensemble run. The biases from the global model, transmitted to the RegCM, have been added to the internal variability of the regional model.

The results of this project's model comparisons are beneficial for the interpretation and use of the models for projecting climate change for the 21st century in West Africa. This study highlights the strengths and weaknesses of the regional model to facilitate its use for climate change projections over the region. More regional simulations using different driving GCMs, greenhouse gases, and aerosol scenarios will increase understanding of model performance and strength, interpretation, and use capabilities. Even with biases and uncertainties, regional climate models offer the opportunity to increase understanding of climate change and increase capabilities to produce more reliable and/or detailed climate projections. These results may also help modeling groups to improve representation processes for the region.

Capacity building and remaining needs

Discussions during AIACC project workshops provided opportunities to develop regional climate simulation capabilities in several institutions in Africa. A PC-based regional climate model, PRECIS v1.2 (UK Meteorological Office), ash been installed at ACMAD (Niamey-Niger) for use in downscaling global climate change projections for climate impact assessments in Africa. This project, managed by a member of the AIACC AF20 team, has contributed to enhance scientific capacity in West Africa to undertake integrated assessment of impact of climate change and climate variability on water resources at regional to sub-regional scales.

The investigators involved in this project have gained better experience with, and are actively involved in, GCM studies, downscaling methodologies, and climate change research. The activities undertaken during the project have enabled the investigators and related institutions to enhance investigation of and provide insights to future climate change in Africa. Capacity building has also led to Ph.D. Dissertations (ongoing) and a Master's Thesis. This AIACC project contributed to fostering physical climate studies in West Africa through the AF20 team and related institutions. The laboratory of the project investigator (LPAO-SF) now regularly hosts scientific meetings. In the past, the laboratory has also hosted researchers active in atmospheric and climate sciences and related disciplines in Africa so that they might convene to develop collaborative research.

National communication, science-policy linkages, and stakeholder engagement

The project also provided an opportunity to initiate dialogue between individuals engaged in the management of water resources and food security and scientists engaged in the study and assessment of climate variability and change (e.g., climatologists, meteorologists). Regional climate model outputs were used to drive soil-moisture balance models for water resource management.

As evidenced, the project team has focused heavily on training and research on regional climate change and applications. This emphasis will help African countries to improve National Communications on climate change and impact assessments.

Policy implications and future directions

The project's activities will also help to further mainstream climate into development policies and plans. It has contributed to regional meetings and forums, and team members are participating on national climate change committees. The scientists' roles are central to the committees since they tend to act as advisers for topics related to climate change science. In addition, two AF20 team members were involved in the IPCC AR4 process.

The work done on climate change detection and attribution, dynamic scenarios generation, and collaborative vulnerability and adaptation studies will be further pursued in the future.

4.5 Food Security, Climate Variability and Climate Change in Sub Saharan West Africa (AF23)

Summary Information

Country: Nigeria
Principal Investigator: James Adejuwon
Administering Institution: Obafemi Awolowo University, Ile-Ife, Nigeria

Research problems and objectives

This project originated from an earlier pilot project aimed at assessing the vulnerability of cereal crop production to inter-annual climate variability and options for increasing productivity. This project aimed to extend this study by also attempting to assess the state of socio-economic development of the peasant farmers. Among the deliverables envisaged by the AIACC project were: a set of empirical procedures for fine-tuning the forecasts of the Meteorological Organizations for use at the local level; a simple procedure for downscaling GCM climate change forecasts for the 21st century; a set of crop-yield forecasts indicating the potential impacts of, and the potential vulnerability to expected climate change; a suite of adaptation options as potential strategies for ensuring maximum crop productivity under each category of anticipated seasonal weather or future climate; a plan for the use of the information by key players in the agricultural sector; a crop of young, well-trained specialists in agricultural meteorology of West Africa with emphasis on Climate Change; and peer-reviewed publications.

Nigeria was adopted as a sample area for Sub-Saharan West Africa due to the fact that it truly represents the climatic profile from the per-humid to the semi-arid ends of the project region and contains all the indicator vegetation types of the various climate types.

The significance of the current study can be seen in the context of the deteriorating state of socio-economic development in Sub-Saharan West Africa characterized by rapidly increasing population, explosive growth of urban centers and largely unsustainable agricultural practices leading to land degradation. Added to these are the negative impacts of the potential changes in global climate as a result of increasing concentration of greenhouse gases in the atmosphere.

Approach

Characterization of current climate was based on the data for the period after 1960 and on 28 synoptic weather stations in Nigeria. An attempt was made to capture the totality of inter-annual variability of climate with respect to monthly maximum temperature, monthly minimum temperature and monthly rainfall for locations representative of the main climate and ecological zones between the coast and the Sahara Desert. Variability indices were computed as the coefficients of variability. In addition linear graphs based on actual records and showing the actual changes in rainfall from one year to the other were also drawn. Regression analysis was used to demonstrate the long-term trends in rainfall and spectral analysis of rainfall data was performed in order to detect any tendency for periodicity.

For climate change projections, both observed and model simulated data were obtained from the IPCC'S Data Distribution Centre in order to maintain the same source. The Climate Change Scenario used in this analysis is an output of Hadley M2 General Circulation Model. The main source of data on socio economic attributes of the country is the Federal Office of Statistics, which collates data from ministerial and non-ministerial departments and generates primary data through continuous and special surveys.

Data on land use changes were sourced mainly from space and air borne remotely sensed imageries. These include: Side-Looking Airborne 1976 (SLAR) Imageries acquired by the Federal Department of Forestry and 1990 low altitude aerial photographs acquired for the Nigerian National Livestock Survey.

Population was projected from a base of 85 million in 1990 with an initial growth rate of 33 per thousand declining to 25 per thousand by 2050. Land use change between 1976 and 1990 was projected into the 21st century with the assumption that its core element is related to the amount of land used for crop production. The latter is driven by population growth and limited by the finite nature of land. Projections of the economy were based on stated government policy and demonstrated executive capacity. The trends indicated by crop production statistics between 1970 and 2000 were explained and the active factors were adopted as bases for projecting crop production to 2050.

For the analyses of sensitivity to inter-annual and intra-annual climate variability bivariate correlation and multiple regression methods were adopted. Impacts of annual climate variability were indexed by a parameter computed as annual yield minus mean annual yield divided by the standard deviation. The assessment of the impacts of climate change on crop productivity was undertaken in ten case studies. Five of the studies adopted incremental scenarios and were designed to demonstrate the relative effects of individual climate elements (i.e. rainfall, relative humidity, temperature, solar radiation and carbon dioxide) on crop yield, using the EPIC Crop Model. The other five case studies adopted GCM scenarios to demonstrate changes in simulated yield of a particular crop, from the baseline of 1961-1990 through three other time slices including: 2010-2039; 2040-2069 and 2070-2099. Only five crops including: maize, millet, sorghum, rice and cassava were investigated.

Vulnerability assessment of the Nigerian Peasant Household was assessed at the level of the component states of the Nigerian Federation. Vulnerability was conceived simply as a function of exposure, sensitivity and adaptive capacity i.e. V = f (exposure, sensitivity, adaptive capacity) and Index of Vulnerability was derived from measures of the drivers of sensitivity of crop yield to climate, and measures of adaptive capacity.

The extent to which adaptive capacity is constrained by existent household characteristics was derived as the proportion of the households affected, which was adopted as a measure of lack of adaptive capacity of householders within each social structure, including: household, community, society, nation and world system. The data thus allows us to compare householders at state level and at regional levels.

The existing capacity for extended range weather forecasting was assessed by comparing observed and forecast weather for the period from 1996 to 2000. Multivariate regression was used to construct additional weather forecasting models with sea surface temperature anomalies, land and sea thermal contrasts, Inter Tropical Convergence Zone (ITCZ) positions and synoptic weather information as predictor variables.

Scientific findings

Current climate

Three anticyclones control general circulation in West Africa i.e. the Azores and the Libyan anticyclones in the Northern Hemisphere and the St. Helena anticyclone in the Southern Hemisphere. Migrating in concert with these high pressure cells are two air masses, a tropical continental (cT) Air from the Sahara Desert and a Tropical Maritime (mT) Air from over the south Atlantic. Between the two air masses is the Inter Tropical Convergence Zone (ITCZ). Because the boundary between the two air masses moves in sympathy with the oscillation of the controlling anticyclones, the belt of ITCZ weather also moves north and south, which is responsible for the characteristic intra-annual patterns of rainfall distribution, specifically, for the differentiation of the dry and the rainy seasons and for the regional disposition of the main climatic types in the sub-continent.

Perennially humid climate (Koppen's Af) characterizes areas south of latitude 7.5ºN. A sub-humid climate (Koppen's Aw) characterizes the region between latitudes 7.5ºN and 9.5ºN. Between the area characterized by the sub-humid climate and the Sahara Desert, the climate is recognized as semi-arid with dominant, arid tropical conditions (Koppen's BS).

Contemporary climate variability

Inter-annual variability of temperature is spectacularly low, averaging less than 5 percent across climate zones and from January to December. By comparison, the coefficient of variability of monthly rainfall varies between 0 and 600 percent. During most of the 20th century there was a general trend towards aridity in most of the stations studied. Fluctuations observed in rainfall were characterized by some regular periodic tendencies as well as strong persistence and temporal dependencies. A general lack of correspondence in the patterns of the fluctuations between seasons was noted i.e. a wet March-April-May is not necessarily followed by a wet June-July-August. Inter- regional disparities in rainfall fluctuations were also observed, which means that while major droughts may be sub continental in terms of area affected; the majority of droughts experienced in each area are local.

Climate change

The most significant changes in climate expected during the 21st Century are with respect to temperature and temperature related parameters. Based on the emission scenarios adopted in the study, changes in minimum and maximum temperatures of the order of 5ºC or more could be expected in certain parts of the country. Such changes are likely to impact multiple sectors including: health, water, biodiversity, agriculture and forestry.

Night temperatures will in general increase at a higher rate than daytime temperatures. Day temperatures may in future attain levels unknown to areas outside the hot desert regions and could produce sultriness and oppressive heat in perennially humid regions. On the average, vapor pressure may rise by as much as 5 to 8 h*Pa with the potential for a significant increase in atmospheric energy, which are likely to result in an increase in the frequency and intensity of stormy weather. A general decrease in cloudiness is also projected. The observed trend towards aridity in Sub-Saharan West Africa during the 20th Century will be put on hold or reversed as the 21st century progresses. There is a possibility, however, that the additional water need created by higher temperatures may not be met by the increases in rainfall.

Uncertainties regarding climate change will most likely be in terms of magnitude rather than of direction. The more significant uncertainties pertain to temperature and temperature related parameters with respect to which the expected changes are relatively large. With respect to moisture, the projections are for an increase rather than a decrease.

Socio economic futures

By 2050 a national population of between 400 - 600 million is expected although it is hoped that targets of population control measures meant for 2010 would have been achieved by then, resulting in population stabilization and ultimately decline. All options for increasing agricultural production through the expansion of cultivated land and through the shortening of the fallow period could likely be exhausted by 2050 and areas used for continuous food crop production would likely dominate the agricultural landscape. Especially in the semi-arid zones, mixed farming will likely dominate agricultural practice and greater use of organic and inorganic fertilizers is expected. Forests will likely be confined to the reserves and the mangrove and fresh water swamp forest ecological zones. Prevailing circumstances would have forced modernization and commercialization on the agricultural sector.

Impacts of climate variability

Crop yield demonstrates little or no sensitivity to inter-annual changes in total annual or total rainy season rainfall. Some crop yields are sensitive to inter-annual changes in the rainfall amounts during the onset and cessation of the rainy season. Crop yield is also significantly sensitive to intra-annual changes in relative humidity, temperature and solar radiation. Significantly depressed yields or crop failures correspond to significant negative anomalies of rainfall that is, droughts. However, significant positive anomalies of crop yield are not similarly related to significant positive anomalies of rainfall.

In general, rice yields have been the least affected among the crops considered in the arid zone case study (maize, rice, sorghum, millet, groundnut and cow peas) possibly because rice is more likely to be irrigated than other crops. Cowpea yields are most likely to be impacted by climate variability followed by maize and millet respectively. Negative impacts of climate are more likely to result from inadequate rainfall in June and/or September, the months of onset and cessation of the rainy season in the case study area.

Impacts of climate change

The indications are that, in general, there will be increases in yield for all crops across the ecological zones as the climate changes during the 21st century. In most cases, the increases are expected to continue until mid-century and then a slow down will likely be observed towards the end of the century. However, yields will still be higher than what they were at the beginning of the century. As should be expected, there will be significant differences between the various ecological zones e.g. substantial increases in the yield of cassava in the drier areas compared to the rain forest zone where there may be a net decrease in yield. The implication of this is that the cassava-growing region will extend northwards. Yields in the wetter forest areas will, however, still remain much higher than yields in the north. Another exception to the general trend is that yields of all the crops will continue to increase right to the end of the century on the high altitude of Jos Plateau.

The increases in crop yield during the first half of the century are probably related to lower water stress as a result of increased rainfall, higher levels of incident solar radiation resulting from less cloud cover and higher levels of greenhouse gas concentration resulting from unmitigated increases in carbon dioxide emissions. The reduction in the yields towards the end of the century could be ascribed to the attainment of supra-optimum levels of temperature and carbon dioxide concentration.

The higher rate of increase of night temperatures in relation to day temperatures may potentially alter the thermo-period to the detriment of biodiversity. Crops and other plants requiring low temperature conditioning during one stage or the other of their life cycles may in the short run survive through autonomous adaptations, but in the long run may have to contend with the possibility of extinction.

Vulnerability of the peasant household

The peasant householder's livelihood, including his food and nutrition, is directly affected by the projected climate change due to his dependence on agriculture, a sector that is by itself exposed and sensitive to climate. Vulnerability of the Nigerian peasant household to climate change is also affected by a number of existent characteristics, which impose limits on adaptive capacity. The most significant is existing poverty, which signifies a lack of resources necessary for adapting to climate change. In addition, relatively low levels of education could also constrain the ability to acquire the technological capacity for combating the negative consequences of climate change. The rate of population increase which at present stands at 28 per thousand could increase the rate of child dependency burden, increase pressure on social infrastructure, and also constrain the capacity to adapt to possible negative impacts of climate change. Based on the analysis, it could be observed that considerable contrasts in vulnerability to climate change exist between the various regions of the country.

Extended-range weather forecasting: a basic adaptation strategy

Extended-range weather forecasting in West Africa has been recognized as the first basic step for all adaptation studies since no reasonable climate adaptation plan can be made without gaining insights into future meteorological conditions of each locale. However an assessment of present capacity found a number of inadequacies. The prediction skill was deemed inadequate because of the low percentage of the "high skill" categories obtained in its assessment. Usefulness of existing capacity to the end users was also low due to: (a) lack of forecasts on the prominent rainfall characteristics such as onset, retreat, length of the growing season and rain-days; (b) lack of forecasts for specific localities, instead of extensive zones; and (c) concentration on the Sahel and relative neglect of the coastal and middle belts of West Africa.

This study attempted to make up for the various inadequacies. Prediction models were generated for the relevant rainfall parameters including onset, retreat, and rain-days. Also, improved models that could make forecasts for specific locations (i.e. towns), and for all the zones from the coast to the Sahel were developed. The study concluded that rainfall characteristics of the region could be reliably predicted, using the rainfall engendering factors of Sea Surface Temperature (SST) and land/sea thermal contrast alone.

Capacity building

Our assessment is that resident capacity for research on climate change has increased considerably compared to that at the initial stages of the project. Strong evidence of our success lies in student participation in the project, especially at the undergraduate level and a high level of performance (one student having received the a first class honors, the third in the 43-year history of the Department of Geography and also an offer of admission from the University of Oxford); the award of a START fellowship for Dr Adeolu Ayanwale, a member of the Research Team; and a third member of the research team, Odeyemi Odekunke, having authored three publications and co-authored two others. Other contributing factors include: the increase in the number of participating researchers from seven to seventeen; participation of core research personnel in AIACC organized workshops; the in-house project seminars; the two-day stake holders workshop in September 2004; an increase in the stock of computing equipment; the visit of Professor C.G. Knight of Pennsylvania State University; and the study visit of one of our students to the University of Cape Town South Africa. There is thus hope that the University will continue to be a centre of excellence for climate change studies in the future. It is recommended that the university strive to provide the necessary assistance to former undergraduates who opted for graduate work in the area of climate change and the progress of those who have opted to study abroad be monitored with the aim of attracting them back to the Department.

National communications and stakeholder engagement

The Principal Investigator of this Project, Dr. Adejuwon, is a member of the National Committee on Climate Change, and has participated in two workshops respectively in 1997 and 2000 designed to facilitate the preparation of the First Communication to the UNFCCC. Dr. Adejuwon has made significant contributions to the preparation of this Communication and was commissioned by the National Committee to prepare a draft of a chapter on Climate Change Scenarios, which he had pointed out as a crucial deficiency in the communication during his review of the same. The outputs of this project informed this draft, which was incorporated as Chapter 4 of Nigeria's First National Communication, submitted in 2004.

Policy implications and future directions

Given the large measure of uncertainty surrounding climate change and its potential impacts, it is recommended that policy should be directed towards the implementation of "no regrets options" for adaptation to, and mitigation of climate change.

With respect to adaptation, perhaps the most important policy implication of this research is the need to improve the adaptive capacity of the peasant householder in terms of poverty alleviation, reduction in the level of child dependency burden, higher levels of education, improved home environment, and improved personal and public health. These are issues synonymous with the United Nations Millennium Goals to be achieved by the year 2015 and also with the mandate of many other United Nations Agencies including UNEP, UNDP, UNESCO, WHO, etc.

There is also a need to develop strategies to increase the resilience of crop production systems and making them less sensitive to climate variability and climate change. Five potential activities identified include: 1) development of institutional capacity in agricultural extension, 2) development of improved seeds and cultivars, 3) removal of biological constraints including pests and diseases, 4) management of soil constraints and 5) reduction of socio economic-constraints.

The strategy of developing an early warning system for anticipating and forestalling the negative impacts of climate variability is also an invaluable "no regrets" option for crop system adaptation since a fore-knowledge of the growing season weather will enable farmers to plan with greater confidence to forestall its negative consequences and exploit its benefits. Since variability will remain a significant element in any future climate, skilful weather forecasting will also remain a valid adaptation strategy, whether or not the climate changes.

4.6 Integrated Assessment of Miombo Region: Exploration of Impacts and Adaptation Options in Relation to Climate Change and Extremes (AF38)

Summary Information

Country: Malawi, Mozambique, Zambia and Zimbabwe (LDCs in general)
Principal Investigator: Paul V. Desanker and Manuel F. G. Ferrao
Administering Institution: Centro Nacional de Cartografica e Teledeteccao (CENACARTA), Mozambique

Research problem and objectives

The overall goal of this project was to assess vulnerability to climate variability and extreme events in selected countries of the Miombo region to guide the development of adaptation strategies. The specific objectives were to:

1. Develop a regional integrated assessment team for the Miombo region;
2. Develop critical datasets, a regional integrated model and other tools for analyzing impacts and adaptation for the region;
3. Conduct case studies of recent droughts and floods in the region (Zambezi River Basin) to document climate – land use – people – ecosystem interlinkages and interactions to guide adaptation planning;
4. Develop scenarios of land use change in relation to IPCC SRES for exploring integrated impacts of climate change and resulting land use changes on production systems;
5. Apply the data, models and case study results to assess vulnerability of life and livelihoods in the Zambezi/Miombo region under future climate change, with particular emphasis on droughts and floods; and
6. Identify critical adaptation plans of action across scales within the Zambezi River Basin – Miombo Region.

Approach

This study used a networking approach by building a community of stakeholders and analysts that collectively formed an integrated assessment team and by involving policy makers at appropriate levels, which provided the mechanism for translating science into policy and policy into practices that were directly applicable on the ground. This approach was motivated by the need to develop responses that address the immediate adverse impacts of climate change i.e. extreme events such as floods and droughts. Quantitative tools such geographic information systems and remotely sensed data were used to evaluate the impacts of the devastating floods of Mozambique during 2000-2002, as well as in the upper Zambezi basin in Zambia. In the case of the prolonged droughts in many parts of Southern Africa, a focus-group approach was used to study local impacts and coping strategies in Zimbabwe, Malawi and Zambia. Later work applied and extended these approaches to study of droughts impacts on the Maasai communities of Kenya. Specific tasks undertaken include:

- Initial Implementation Workshop: Key investigators met to finalize planning for this project to develop a detailed timeline of activities and deliverables, refine the approaches and design of case studies, and develop synergies with other funded projects.
- Building Knowledge Base and Case Studies on Local Coping: This included the building of a comprehensive bibliography on Africa and Global Change to support synthesis reviews and as a basis for communicating with policy makers. Case studies of the impacts of recent floods in lower Zambezi, the Lower Shire and parts of Zimbabwe and Zambia were also conducted by reviewing online data archives of various organizations. Field interviews and local assessment of coping strategies were carried out in Malawi, Zimbabwe and Zambia.
- Climate Database Development: Weather data from national archives was collated and entered into a regional database. Both station and gridded data were analyzed to derive trends and occurrence of extreme events and patterns of other climate indices.
- GIS Data Preparation: Spatial data were assembled into a GIS database to support various assessments. Animated gifs of climate data were prepared for the region (as well as whole of Africa) based on CRU data and climate change scenarios to provide visuals for the project.
- Model Development, Analysis and Assessment, including "Summer Institutes": A vulnerability and adaptation (V&A) assessment tool called PRIVA was developed for use in developing NAPAs in LDCs. The adopted methodologies for NAPA are now in use by all LDCs, and there has been increasing interest from non-LDCs to apply this approach in their V&A work. Regional training workshops on NAPA preparation applied PRIVA, as well as provided valuable feedback.
- Dialogue on Southern Africa and Global Change: This included national level workshops with stakeholders including special workshops for senior policy makers. Briefings on climate change and on research findings by national scientists were provided followed by discussions on how to best prepare for adverse climate change. A senior policy maker from Malawi attended the UNFCCC COPs, and participated in a policy panel at Adaptation and Development Days in Montreal, Canada, and other sessions of the Subsidiary Bodies.

Scientific findings

A key finding of this study was the elaboration of a vulnerability framework and the development of an assessment approach for use in defining NAPAs in LDCs. The vulnerability framework was developed using the IPCC model in which vulnerability is defined as a function of climatic hazard, impact potential, sensitivity to climatic hazard, coping range and coping ability. A given system is thus defined in terms of its functional dependence on climate.

Adaptation can then be defined as those activities designed to reduce or totally eradicate vulnerability by addressing the individual or combined components of the vulnerability. The various types of intervention for adaptation include: reduce hazard risk/remove hazard source; reduce/avoid exposure to climate hazard; adjust/modify system to reduce impact potential; and enhance adaptive capacity/coping ability. For examples see Table 4.1.

Key messages/main observations

The following observations were made throughout the case studies in this project, and through interaction with various stakeholders in the conduct of the research. These observations are listed in particular order:

- Adaptation is local/place specific/context specific.
- Absence of evidence is not absence of impact or need for adaptation.
- Additional funding is needed to address adaptation.
- Local coping strategies are not always optimal.
- Vulnerability is multidimensional, caused by multiple factors besides climate.
- Vulnerability is caused by multi-scaled factors from local, regional (basin-wide) to global factors.
- It is impractical to disaggregate climate change from disasters and other adverse impacts in terms of responses, preparedness.
- Decisions on dealing with climate change impacts are not always based on objective reasoning: e.g. rebuilding cities such as New Orleans after Katrina - not based on objective reasoning, rather on policies and emotion.

Lessons from Katrina: The Katrina disaster in the United States helped bring to light some experiences and lessons that apply generally to all disasters, and in future, will have a bearing on climate-related disasters. Some of the key lessons learned from this experience include:

- Public response to Katrina in terms of preparation and responses to warnings was in large part a direct result of effective early warning systems.
- The ignorance of warnings by some people is an indication that the public will not always take precautionary action when faced with clear risks.
- The sick, poor and the weak are most vulnerable.
- Race and ethnic background matters in decision making.
- Economic welfare of households is a major determinant of ability to cope with rapid impacts.
- Assistance from the government is dependent on many factors that are hard to predict, making local preparedness and coping ability critical in rapidly evolving events.
- Certain events act as triggers or tipping points for social change and action.
- Sometimes under-qualified leaders may hold a powerful decision-making role (the Brownie factor), which could impact response to such disasters.
- Scenarios are a useful planning tool and can help develop response strategies.

Table 4.1: Main adaptation activities, interventions and delivery methods

Adaptation Goals / Expected Outcomes	**Main line of intervention and delivery**
Minimize physical exposure to climatic hazards	• Flood control measures such as dams, levees, early warning systems, improved drainage, river re-routing, improved land management e.g. watershed afforestation to manage runoff, preservation of wetland systems to manage runoff • Drought mitigation measures such as improved water management/water harvesting • Re-zoning sites vulnerable to landslides • Frost control measures such as watering or covering crops/plants at night • Migration or relocation away from flood zones, coastal areas, etc • Global mitigation of climate change through reductions in GHG emissions • Improved water treatment to avoid contamination from flood waters, salinization
Avoid or reducing potential for adverse impact (climate proofing)	• Modify climate-system relationship such as through manipulation of thresholds or coping ranges, dependence on climate (e.g. reducing dependence on rain-fed agriculture), etc • Economic instruments to reduce sensitivity to climate e.g. insurance • Manipulate systems (such as ecosystems and infrastructure) to withstand new climatic conditions through crop/tree breeding or genetic manipulation

Enhance adaptive capacity and resilience (address determinants of adaptive capacity)	• Increase wealth/income especially of rural poor through economic diversification, access to micro-finance • Modify climate-system relationship such as through manipulation of thresholds or coping ranges, dependence on climate (e.g. reducing dependence on rain-fed agriculture), etc • Reduce risk to climate change and variability through (micro-) insurance • Improve ecosystem integrity through reduced siltation and erosion control, fire control, eradication of invasive species, avoid overgrazing, rehabilitate degraded areas
Improve planning to take changing climate into account to avoid an adaptation deficit and to remove any barriers to adaptation	• Modify planning processes to integrate climate change and adaptation into sectoral and national plans (mainstreaming) • Remove barriers through policy review and/or development of new policies to facilitate adaptation
Create and manage information to facilitate adaptation	• Build knowledge bases through research, monitoring, extension and outreach, early warning systems, etc., to improve adaptation planning and implementation • Build capacity in communities to take climate change into account

Capacity building outcomes and remaining needs

The Miombo AIACC project built capacity for long-term climate change research through the following:

- Creation of baseline datasets in formats ready for use with modeling tools, including all required data inputs for the development of national adaptation programs of action (NAPAs) as described in UNFCCC/SBI documents (UNFCCC/SBI/2001/7). These datasets were developed in collaboration with national institutions and will be integrated into future analyses.
- Regional scientists were trained in developing the data inputs and models and in applying these models to determine climate impacts and adaptation strategies, as well as for reporting requirements through their national communications to the UNFCCC. Participants from this project are active in national communication and NAPA projects and several are active in international processes such as in the UNFCCC Conferences of Parties (e.g. Zulu, Kazembe, Desanker, Sitoe, Mushove [before his passing], Matsika). Several PhD students have enriched their educational programs (Mushove, Mwangi, Chavula, Zulu) through access to data, field resources and modeling support.
- Project participants Zulu and Desanker participated in the design and implementation of regional training workshops on NAPA (4 regional workshops and one global workshop on NAPA). All LDCs were trained in NAPA preparation and in resources such as PRIVA, the NAPA Primer, sample NAPAs and technical reports (through the LEG).
- The project contributed towards the completion of 4 PhD's (Mushove at Wits; Zulu in Illinois; Chavula at Univ of Minnesota; and Mwangi at Penn State) and one MS degree (Mulando, Netherlands). The project supported the students' field data collection and provided them access to databases within the Miombo Network. The students in turn contributed in the creation of data tools and their research is of relevance to the broader regional goals.
- Remaining needs: The next step should be to set up a live data server that includes climate change scenarios and projections through an active website for use by different stakeholders. Time and resource intensive regional climate model runs could be available online for ease of use by others. There is also the need to better integrate findings of this study and others into local university curricula.

National communications, science-policy linkages and stakeholder engagement

The scientists active in this project were active participants in their national communication projects, and will be more so during the preparation of second national communications, a process that is beginning for these countries. Participants also contributed to NAPA activities in Malawi, Mozambique and Zambia.

The project resulted in active interaction with policy makers and stakeholders in all four countries, including Ministers, Principal Secretaries and other diverse groups. In Malawi for instance, several Ministers and Principal Secretaries were in regular contact with project staff, and this has resulted in a very fruitful partnership beyond the immediate objectives of the AIACC project. Project scientists are called upon to advise on other climate change issues such as CDM, and in representing their country as delegates to the UNFCCC Conference of Parties.

Policy implications and future directions

The findings from the NAPA/PRIVA work, and the sample NAPAs that were prepared for Malawi and the Maldives, helped establish policy for NAPA preparation under the UNFCCC. An important result was the conclusion that NAPAs could be completed without the need for a comprehensive assessment involving methods commonly used for national communications, including use of climate change scenarios and modeling of impacts. The case studies have provided useful insights into local coping strategies, and results were presented at a UNFCCC workshop in New Delhi on this subject, and contributed to a greater acceptance of local coping strategies as viable adaptation activities.

4.7 Impacts of Climate Change, Vulnerability and Adaptation Capacity in the Limpopo Basin: The Case of Eastern Botswana (AF42)

Summary Information

Country: Botswana
Principal Investigator: Dr. Opha P. Dube
Administering Institution: The University of Botswana (UB), Gaborone, Botswana

Research problem and objectives

The Limpopo Basin of Botswana is an area that experiences unpredictable climate and frequent droughts, which affects water availability and food production and subjects local communities to severe food stresses. Over the recent decades, recurrent drought has become increasingly common such as, for example, the 1983-1987 and 1991/92 drought events. The Basin is also home to the largest population of poor households in Botswana, many of which are also female headed. Besides, there is a high dependence on primary resources due to poor economic diversification, with nearly 70 percent of the country's population relying on subsistence agriculture. These factors contribute to an increasing vulnerability to drought impacts and lead to the exacerbation of conditions of rural poverty. Although government intervention is often required to help relieve food stresses there is a lack of any focused programs that address vulnerability to climate variability and change in national development plans. This is largely due to inadequate knowledge about the exact nature and level of the vulnerability of food and water resources in the Limpopo Basin region.

In response to these shortcomings, this study was designed to build capacity in climate variability and climate change research in the Limpopo Basin of Botswana. The aim was to develop locally relevant information on climate stresses on the food and water sectors and systems, which could then serve as the foundation for planning adaptive responses. The specific objectives of the study are:

- To determine the factors influencing the primary food and water resources in the Limpopo Basin
- To establish the level of vulnerability of these resources to climate variability and change, keeping in mind the interactions between climatic and socio-economic factors.
- To determine community responses to climate impacts on food and water resources
- To assess the effectiveness of existing policies, programs and institutions for reducing the vulnerability of local communities
- To explore cost-effective and locally feasible adaptation options
- To increase awareness on climate change issues at all levels by engaging affected communities, NGOs, industry and Government at different stages of the project and by contributing to peer-reviewed papers, educational curricula, seminars, conferences and other modes of communication.

Approach

The study examined a range of interrelated factors in food and water resources: climate, water supply and demand, biomass energy, conventional food production systems, institutions, government policies and programs, and the role of non-climatic stressors. For this purpose, biophysical and socio-economic data was collected from three study sites: 1) the North East District with relatively higher rainfall; 2) the Bobirwa sub-district in the southeast with the least rainfall; and 3) the Kgatleng District in the south with rainfall comparable to the North East District. Current climate data was based on available records while the outputs of four global circulation models (GCMs) and two socio-economic scenarios were used to determine future climate parameters. Socioeconomic data was obtained using standard sampling methods in conjunction with archived data on climate, livestock, wildlife, veld products and so forth. Spatial information data sources like topographic maps, aerial photographs and satellite data helped to spatially characterize land cover/land use types, biomass, fire and land degradation.

The various techniques used to obtain quantitative and qualitative socio-economic information included survey instruments such as participatory rural appraisal, questionnaires, interviews, and workshops for various sectors of the community including farmers, heads of households, youth, women groups, NGOs, and central and local government officers. This information was supplemented with secondary sources including Government reports. The socio-economic information helped to assess communities' views on the types and status of available resources, the roles of climatic and non-climatic stressors, existing institutions and policy interventions, and options for coping with climate variability.

Scientific findings

Climate

The Limpopo Basin is characterized by warm summers and cool and dry winters. Mean monthly maximum temperatures of 33ºC and a mean monthly minimum of 5ºC are typical. Rain usually occurs over the summer period, between October and April, and mean annual rainfall in the basin ranges from 370mm in the Bobirwa area to nearly 550mm in other parts. In the North East District, rainfall is influenced by the Inter-Tropical Convergence Zone (ITCZ) while the Kgatleng District and other southern areas receive limited rainfall from the moist maritime easterlies due to the relief in South Africa. The Bobirwa Sub-District is at the tail end of both systems and is the driest part of the basin. The basin is also influenced by the El Niño Southern Oscillation and is prone to frequent drought, which occurs nearly every 2-3 years, when both or one of the rain bearing systems fails.

Results from 4 GCMs also show a warming trend over the basin and an increase in the minimum temperatures, which usually occur in July, has already been noted. Over the next century, temperatures are projected to rise by 1 - 3°C with a warming of 2°C likely by 2050. Rainfall is expected to become more unpredictable in the future.

Water resources

Water scarcity is one of the predominant problems and nearly all of the Limpopo tributaries are ephemeral with an average flow period of 10-70 days per year. Population and economic growth and rising living standards are expected to result in a further increase in water demand. An investigation of water supply in Kgatleng, using runoff coefficients (ROCs), found that factors like erratic rainfall, heterogeneity of the landscape, and spatial and temporal differences in land use/land cover influence ROC variations. The ROC computed with a water balance model showed an increase of 0.4 over the 1971-1980 period and of 0.48 over the 1991-1998 period, indicating climatic influences on the ROC with a greater effect over the 1991-1998 period. The ROC computed using a land use/land cover model over the same period showed a decrease from 0.54 in 1973 to 0.50 during the 1994-2000 period. This can be attributed to changes in land cover resulting from the intensification of agricultural activities, development of infrastructure, expansion of settlements and population growth. The abandoning of several fields due to drought and other socio-economic changes in the late 1990s to 2000 period explains the stable runoff during these years. Future forecast through the year 2020 using the optimal Artificial Neural Network (ANN) architecture showed the likelihood of a gradual increase in ROCs provided that land use/land cover conditions remain stable. This could lead to flash flood events in the basin even with a marginal decrease in precipitation. Accelerated soil erosion due to land degradation may also be experienced.

For the water demand analysis, the potential impact of climate variability and change on domestic water consumption was investigated for low, medium, and high-income groups around the Kgatleng District and Gaborone city over a period of 3 years using the HADCM3, CCMA and CSIRO climate change models and the IPCC A2 and B2 scenarios. The results showed an increase in water demand with increasing temperature for all income groups, with a higher increase noted for the low income and rural households with poor housing structures and lack of air conditioning. The impact of rainfall on water consumption was also significant for the rural and low-income groups who depend on surface water for domestic needs. Future climate scenarios project a net decrease in rainfall and an increase in temperature by 2089 for the Gaborone and Kgatleng, which would likely result in an increase in domestic water demand at all income levels. This increase would be in addition to that due to the impacts of population and economic growth. At the same time such water deficits can in turn negatively influence economic growth.

Conventional food production sectors

Among the food production sectors, the crop and livestock sectors were investigated. In the Kgatleng District, the crop sector was studied by means of the farming systems approach (FSA) and via interviews in selected villages, while in the other study sites a more general survey and analysis of crop yield statistics was conducted. For the livestock sector, communal and freehold land tenure systems were examined in the three study sites.

In Bobirwa, drought conditions are near perpetual, making arable agriculture almost impossible. Agriculture is more common in Kgatleng though drought often results in low crop yields and about a 60 percent decline in the practice of agriculture has been noted. It is projected that drier conditions due to climate change will worsen the performance of rain-fed arable agricultural in the entire basin, necessitating the need for viable adaptation strategies. To cope with drought and increase crop productivity, several government programs such as the Arable Lands Development Programme (ALDEP), the Financial Assistance Policy (FAP), the Accelerated Rainfed Arable Programme (ARAP; now discontinued) and the more recent National Master Plan for Arable Agriculture and Dairy Development (NAMPAAD) have been introduced with varying degrees of success. At the community level many farmers have adopted the use of tractors, which are subsidized by the government, and not only enable faster plowing and therefore planting before the moisture dries up but also serve to replace draught livestock lost to drought conditions. There is also a shift to drought resistant crops such as beans and sorghum instead of maize, which is restricted to exceptionally wet years. Other potential strategies suggested by farmers include the use of rainwater catchment and drip irrigation systems. Communities also cope with reduced farm produce by purchasing food, though this requires a constant cash flow that usually comes from sources such as temporary employment and remittances from relatives employed in cities. Overall there are few alternative rural livelihood possibilities, which were stated to be an important necessity during farmer consultations.

In the livestock sector, goats and cattle are commonly reared but cattle farming is now predominantly practiced by all categories of farmers. Cattle are however more vulnerable to drought than goats and a recent decline in cattle numbers has been noted, with communal areas being the most affected. Drought and high temperatures result in low animal breeding rates, poor growth rate and high mortality. Other factors such as poor management, shortage of land, land tenure of livestock holdings, livestock management policy, climate, and disease have also been implicated in livestock loss. Basically a combination of non-climate stressors and frequent droughts was noted as the primary cause of the decline in rangeland conditions and productivity, leading to impoverishment, marginalization and further environmental degradation. Subsistence farmers are affected the most since they often have limited options to fall back upon.

Provision of water and feedstock was considered to be the most viable drought coping strategy by cattle farmers though this approach has not proven very successful during past drought episodes. This is mostly because livestock feed is expensive and unaffordable for poor farmers and for those with large herds. About 60 percent of farmers acknowledged the positive contribution of government interventions including disease control and programs such as ALDEP, ARAP, and FAP, which had aspects that benefited livestock. The Small Livestock Owners in Communal Areas (SLOCA) programme, which aims to improve livestock production among small livestock owners outside freehold ranches, was also highly valued. Other coping strategies include livelihood options in wildlife conservation and utilisation establishments and tourism enterprises on private farms. Communities were divided in their opinions about assuming responsibility in controlling environmental degradation with communities from the North East stating the need for a greater governmental role.

Non-timber forest products sector

The Limpopo Basin is rich in forest products such as medicinal plants, thatching grass, biomass energy and the Phane caterpillar (larvae of *Imbrasia belina* moth). This study examined biomass energy and Phane as examples of important veld products contributing to household food security in the basin.

The Phane caterpillar is high protein delicacy, which thrives in the *Colophospermum Mopane* woodland and is also a source of food security during periods of crop failure. The effect of climate on the Phane was examined for the North East Francistown area and Selibe Phikwe and the central-Palapye area in Bobirwa. Spatial variations were observed between the study sites reflecting spatial differences in caterpillar production in different years. An annual fluctuation in Phane production was also observed in relation to rainfall amounts, particularly for the 1999-2004 period when Phane exports showed a decrease with decreasing rainfall. The timing and amount of the first rains were found to be important in triggering phenological development in the host mopane woodland and the emergence of the Phane moth. Future climate scenarios show increasing aridity over Botswana, which could negatively impact caterpillar production. Nonetheless, there is still significant potential for enhancing community food security through the sale of this product if appropriate packaging and marketing facilities are developed. There is however a need for regulated harvesting for conservation of the Phane and general control of deforestation to protect its habitat.

Fuel wood is another important forest product that is used as an energy source for cooking and is also traded for income generation. Due to the lack of sufficient fuel wood production figures, standing woody biomass stocks were measured to assess available fuel wood resources in the Limpopo Basin. Overall, biomass stocks were found to be low though there are spatial variations with parts of the North East District showing a reasonable resource base and versus its relative absence in the other sites. Normally relatively dry, mature trees are preferred for commercial fuel wood trade but a scarcity of such trees due to intensive harvesting has led to the cutting of healthy trees that are then left to dry, thus reducing the regeneration capacity of the woodland. In areas of *C. mopane* woodland there is also land use competition between fuel wood trade and the caterpillar trade, though the two activities are often carried out by the same set of people. There is therefore a need to balance both trades sustainably for example by restricting fuel wood harvesting to old or dead trees. Under the current climate, Phane habitat preservation should be prioritised since it brings higher returns and can enhance coping with climate extremes.

Wildlife and tourism resources

Botswana is one of the prime tourist destinations in Africa due to its vast wilderness and rich wildlife resources as well as the stable political and economic climate. Wildlife tourism contributes to about 4.5 percent to the Gross National Product and is marketed as a low volume, high priced attraction to protect the resource base. In the Limpopo Basin a variety of wild animals and birds existed as late as the early 19th century, but since then various species like roan, sable, tshessebe, gemsbok and hartebeest have disappeared. This is largely due to the impacts of human developments and land use conflicts that destroy habitats and affect water resources in addition to climatic factors. Lately there has been some improvement in the wildlife population but this is mostly restricted to the freehold farms that offer recreation and tourism facilities. This can be attributed to government policies and regulations that support game ranching and protect wildlife resources; international conventions such as CITIES; and an increased investor interest in commercial wildlife management based economic activities. Game farming is also generally considered to be more suitable than cattle rearing due to the higher resistance of wild animals to climate extremes and diseases and the low infrastructural investment necessary. However wildlife ranching as a livelihood option is only affordable to owners of large Freehold farms who have the economic means for such a venture. It also offers very limited employment opportunities for communities.

Besides wildlife and game reserves, the Limpopo Basin is also endowed with rich cultural resources that include various ruins; rock paintings; pottery; folklore, songs and dance; and museums. However the varied tourism resources have not been fully exploited mainly because of a lack of public awareness, a lack of community involvement in tourism and heritage management, and a lack of skills and education. The National Ecotourism Strategy therefore calls for the education of host communities and their active involvement in all aspects of tourism development and management. Unfortunately efforts taken by the Wildlife and Tourism Department so far have been inadequate due to the lack of capital resources and a lack of skills at the community level. Other options such as joint venture partnerships between tour operators and local communities can also be explored to help establish tourism as a livelihood option.

Policies and institutional frameworks at the community level

The influence of institutional and policy frameworks on the vulnerability of rural communities and their coping capacity to drought was also examined. The basic institution that defines each village in the community is known as the Kgotla. It is headed by a Chief and operates as a decision-making body. The central and local Governments communicate with communities via the Kgotla through a number of rural development agencies and organizations. Among these, the Village Development Committee (VDC) works through the Kgotla and helps disseminate information on various government policies and programs and assists in implementing policies aimed at poverty alleviation and building community resilience to different stresses such as drought. The VDC also identifies and communicates community needs to the government.

However community involvement in government rural development efforts tends to be poor, as does participation in the Kgotla meetings where these programs are disseminated. This has been attributed several factors such as the lack of any power with the Kgotla, which only receives and implements government policies; loss of interest in traditional institutions such as the Kgotla; lack of community spirit of self reliance; over-dependence on government programs; and alternate source information than the Kgotla i.e. the media. The lack of participation increases vulnerability to drought and results in an increased reliance on emergency programs such as Labour Based DRP, which is now one of the primary livelihood sources in the North-East District. A close evaluation of rural development policies and programs is therefore necessary in order to enable an increased empowerment of communities and encourage their increased involvement in development initiatives.

Capacity building outcomes and remaining needs

Capacity building in terms of climate change research and the development of locally relevant information was achieved at multiple levels. Nine members of the academic staff of the University of Botswana were introduced to climate change issues and their implications for Botswana, which resulted in climate change being included as a research topic and being increasingly incorporated into the curriculum of the Department of Environmental Science. In addition, a short course on climate change for stakeholders outside the University is also being offered by the department. Four other staff members indirectly involved in the project also benefited in terms of acquiring skills in climate change research tools and techniques, developing a knowledge of impacts and vulnerability issues and participating in capacity building at the grassroots level.

Most of the project participants from the University were young researchers and students who acquired valuable scientific knowledge, research skills and gained insights in project implementation and management. Three of these staff members have taken up PhD research on this topic of which one is now complete. Other students that participated in this research include one MPhil student, five MSc students and one undergraduate student besides an additional 20 university students (undergraduate to PhD level), eight Cambridge-level students and two primary school level students that contributed as research assistants.

Despite the significant gains in capacity, there is still a need to develop ability to interpret and downscale regional climate change and socio-economic scenarios to a finer scale – at the basin level, for example - and to provide relevant information to decision-makers and the general public. There is also deficiency in the ability to produce descriptive studies from modeling results and to extend results beyond case study sites and over time. A lack of peer-reviewed publications is also an issue, which needs to be addressed by encouraging collaborations between the junior staff and the more experienced researchers. The research base developed during this project needs to be sustained and built upon in order to maintain a momentum in the generation of up-to-date information on climate change.

National communications, science-policy linkages and stakeholder engagement

Project participants have contributed to the evaluation of activities of the first National Communication to the UNFCCC and contributions to the planning and implementation of the 2nd National Communication report are currently underway. Most of the Science –Policy linkages developed during this project have been achieved through ties with the National Climate Change Committee (NCCC) under the UNFCCC National Focal Point (NFP), which is formed by representatives from different government institutions. The project also partnered with the Department of Meteorological Services (DMS), which facilitated participation in IPCC outreach activities and made possible the communication of project results to leaders in academia; members of Parliament, the Cabinet, and the House of Chiefs; the private sector; senior natural resource managers; and the media. One project researcher has also served on the UNDP GEF Small Grant Committee.

With respect to stakeholder participation, a consultative meeting with relevant government officers and NGOs was held during the planning stages of the project to enlist their views on project implementation. Participatory data collection activities in the case study areas also engaged key informants and created linkages between various government extension officers, District Officers, Land Boards, NGOs and the local communities including community-based organizations. Engagement of stakeholders was further facilitated by a supplementary grant provided to the project for information dissemination workshops, which enlisted the participation of over 200 community members. The project's report is also available with the National Archives Library where it can be accessed by the public. However, despite these efforts, much still remains to be done to raise the profile of climate change among the general public as well as among the private sector, NGOs, and government.

Policy implications and future directions

A major policy deficit is the lack of any consideration given to drought impacts in the national budget and in the 5-year National Development Plans. Existing policies fail to address vulnerability and adaptation to drought and water resource shortages as a permanent feature of Botswana's environment and these conditions tend to be treated as emergency situations instead. In order to initiate planning on focused adaptation to climate extremes in Botswana, detailed information on the manifestation of climate change at the local scale, for example, at a district /watershed scale will be necessary. This calls for national/regional investments on improving capacity to interpret, generate, and use climate scenarios that can then inform appropriate policy decisions. In addition policies that seek solutions on water supply and management need to be designed as participatory communities activities in order to ensure their effectiveness. Some of the potential options that surfaced during interactions with community members include, water conservation, rainwater capture, and control of stocking rates to avoid land degradation.

Although wildlife will eventually be affected by climate change, game farming has been shown to be less vulnerable to dry conditions than domestic animals. Forward looking policies that aim to facilitate market development for wildlife related recreation and tourism and in conservation and preservation are therefore required. Other livelihood diversification strategies such as, for example, the development of natural products either as direct food sources or for medicinal purposes, are also necessary. Given the general lack of any financial buffers for most of the existing rural economic activities (e.g., insurance for environmental hazards), policies that facilitate the development of risk-spreading mechanisms among rural communities would be important aspects of planning for adaptation to climate change. In addition, the engagement of international funding organizations and NGOs is also crucial in assisting communities in Botswana to adapt to climate change.

4.8 Costs and Benefits of Adaptation Projects: Examples from South Africa and the Gambia (AF47)

Summary Information

Country: South Africa, The Gambia
Principal Investigator: Jabavu C. Nkomo
Administering Institution: Energy Research Centre, University of Cape Town, Cape Town, South Africa

Research problem and objectives

So far, there has been little work done either by the climate secretariat or by any bilateral or multilateral funding agencies on developing evaluation tools for adaptation projects despite the increasing importance being given to adaptation funding in the UNFCCC. The IPCC's Third Assessment Report predicts that Africa will suffer the most severe impacts from climate change, and African policy-makers need to carefully examine the trade-offs between the benefits and costs of adaptation projects, as well as mitigation costs and adaptation costs. This study therefore aimed to develop the capacity to estimate and compare the benefits and costs of projects in natural resource sectors that reduce the expected damages from climate change in South Africa (the water sector) and The Gambia (the agricultural sector).

The first part of the study used well-established principles from economic benefit-cost analysis to develop a framework to estimate the economic benefits and costs associated with the expected climate change damages avoided by a development project that does not take climate change into account. These benefits and costs could then be compared to the case where planners incorporate expected climate change into the project assessment. The second part consisted of demonstrating this methodology using a selected adaptation project. The ultimate objectives were to examine the benefits and costs of avoiding climate change damages in two cases: (i) through structural and institutional options for increasing water supply in the Berg River Basin in the Western Cape Province in South Africa; and (ii) by examining adaptation strategies for millet in The Gambia.

Part I. Adaptation to Climate Change: The Berg River Basin Case Study

Runoff from the Berg River Basin constitutes the major source of water supply for the Cape Town metropolitan region and for irrigating 15 000 hectares of high value crops, the bulk of which is exported and represents an important part of the regional and national economy. In the last three decades, urban water consumption has increased by roughly three-fold in metropolitan Cape Town and a continued rapid growth rate is expected due both to the in migration of poorer households and economic development. This has resulted in an increasing competition for water, which is further exacerbated by a fairly high inter-annual variability in rainfall and runoff in the basin as is evidenced by a recent drought that left the reservoir at about 30 percent of average capacity at the beginning of the irrigation season in 2004-2005. As a solution to this problem the Berg river (Skuifraam) dam was commissioned (construction began in 2004) although it did not take into account climate change impacts.

In this context, the objectives of this study are to develop and implement the necessary analytical tools to: estimate the potential impacts of alternative climate change scenarios on water supply and demand in the basin via changes in runoff, evapotranspiration and surface evaporation; convert these physical impacts into monetary losses (or gains) for different groups of farmers and urban water users; and estimate and compare the benefits and costs of the storage and water market options for avoiding climate change damages, with and without accounting for expected climate change in the planning for these options.

Method of estimation

To achieve these objectives the Berg River Dynamic Spatial Equilibrium Model (BRDSEM) was developed as a water planning and policy evaluation tool to compare the benefits and costs and economic impacts of alternatives for coping with long-term water shortages due to climatic change. It is a dynamic, multi-regional, non-linear programming (DNLP) model patterned after the 'hydro-economic' surface water allocation models developed by Hurd et al (1999, 2004) for five major river basins in the US.

The core of BRDSEM, shown in Figure 4.3 is made up of three linked modules:

- *The Intertemporal, Spatial Equilibrium Module* consists of a series of linear equations that characterize both the water balances over time in specific reservoirs and the spatial flow of water in the basin, linking runoff, reservoir inflows, inter-reservoir transfers and reservoir releases, to urban and irrigated agricultural demands for water.
- *The Urban Demand Module* simulates the demand for urban water for seven urban water uses.
- *The Regional Farm Module* consists of seven regional dynamic linear farm models (one for each farm region) that simulate the demand for agricultural water in the Upper-Berg River.

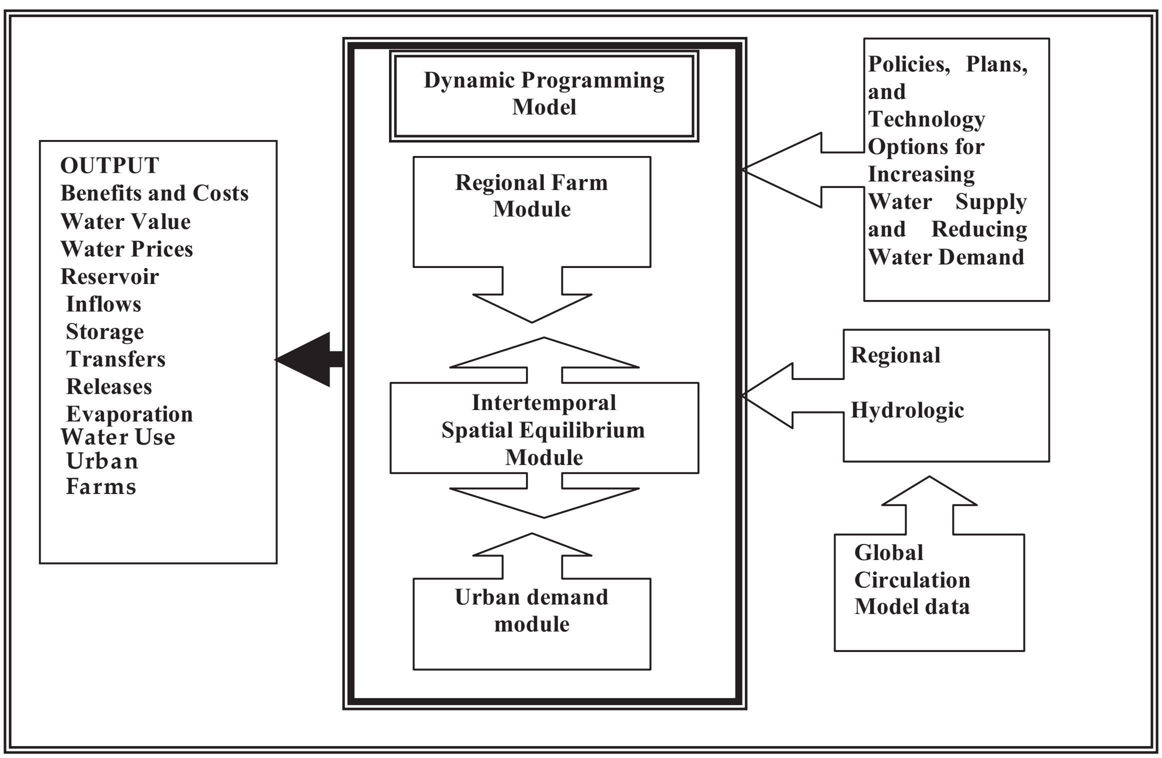


Figure 4.3: Berg River Spatial Equilibrium Model (BRDSEM) Schematic Diagram

There are three external sources of information to BRDSEM i.e. a Global Circulation Model; a Regional Hydrologic Model; and inputs about policies, plans and technologies.

The economic value of the net returns to water were estimated for three climate change hydrology scenarios, two different levels of urban water demand, and four different policy regimes for allocating water, with and without the possibility of optimal storage capacity behind the Berg River Dam.

A framework developed by Callaway et al (1998) and Callaway (2004a and 2004b) was also used to estimate the benefits and costs associated with adapting to climate change for two possible water allocation policy regimes: a) adequate water supplies for urban and agricultural water demand (upper and lower bounds fixed on urban water demands and water diversions by regional farms) with the possibility of storage in the Berg River Dam; and b) efficient water markets (no bounds on urban water demand or agricultural diversions) with the possibility of Berg River Dam storage. This was done for three different climate change scenarios. The economic measures of this evaluation include, climate change damages; net benefits of adaptation; imposed damages of climate change; the costs of caution; and the costs of precaution.

The above set of measures applies to storage capacity adjustments made in anticipation of climate change for individual water allocation regimes, not for changes in the regimes themselves. We used the same framework to estimate the 'partial' net adaptation benefits associated with both: i) substituting a system of efficient water markets in (b) above for the most highly constrained allocation system, represented by (a) above and ii) the addition of optimal reservoir capacity on top of the change in allocation systems. This was done for the climate change scenarios in the near future and the distant future. This analysis is important because ex ante reservoir storage decisions are subject to ex ante climate risks (i.e., by planning for the wrong climate change), while changing water allocation systems is a 'no regrets' measure, not subject to climate risk.

Main conclusions of the Berg river study

The important conclusions from our study are as follows:

- From a benefit-cost perspective, construction of the Berg River Dam at capacity levels that were optimal for the climate scenarios used in this analysis appear to be justified on the basis of economic efficiency.
- From a benefit-cost perspective, the implementation of an efficient system of water markets, with or without construction of the Berg River Dam, resulted in the highest net returns to water compared to other simulated allocation systems under all climate and urban demand scenarios.
- Agricultural water use was very robust to the simulated changes in climate, urban water demand assumptions, and the presence or absence of the Berg River Dam compared to urban water use and water allocation policies.
- Urban water consumption, by contrast, fluctuated much more in response to both climate change and changes in water allocation policy.
- Simulated climate change damages were relatively and absolutely much greater under our representation of the current allocation regime (a) than under the efficient water market regime (b) at high urban demand levels.
- The impact of adaptation by adjusting reservoir capacity from partial to full adjustment was relatively small in both a and b.
- The most significant reductions in climate change damages came from instituting a system of efficient water markets in b for our representation of the current allocation regime (a).

Overall, the analysis of the costs of caution and precaution did not provide any unambiguous results that would allow one to determine if it would be less costly to anticipate climate change or plan cautiously. It was found that substituting markets for the existing allocation system substantially increased the simulated marginal cost of water to urban water users and led to reduced consumption on their part. This would however have adverse consequences for poor households in the Cape Town Metropolitan region.

Part II. Adaptation to Climate Change for Agriculture in The Gambia: An explorative study on adaptation strategies for millet

In this case an adaptation benefit-cost framework as well as analytical tools and procedures were developed and then applied to the predominant crop in the Gambia – millet (*Pennisetum typhoides*), in a rainfed environment. Rainfall in the Gambia is characterized by significant variability on both the temporal and spatial scales, with the somewhat frequent occurrence of drought-related situations of greater concern. The choice of millet stems from its ability to withstand low moisture situations, such that any significant drop in yield linked to moisture stress, will signify a greater impact on the other crops.

Method of estimation

The study used observed climatological data from the Meteorological Services of the Gambia (rainfall & temperature) and the Climatic Research Unit data set of the University of East Anglia, UK (solar radiation, relative humidity and wind speed) to characterize the reference climate (1961-1990). For future climate, the study used the Max Plank ECHAM4 and the Hadley Center's HADCM3 Global Circulation Models for the A2 and B2 IPCC SRES scenarios. Whilst ECHAM4 predicts increases in rainfall and temperature for the Gambia, HADCM3 predicts increases in temperature, but a reduction in precipitation. Statistical downscaling technique was used to obtain rainfall, and minimum and maximum temperatures from the GCMs for specific locations in The Gambia, for the near future (2010 – 2039) and the distant future (2070 – 2099).

To assess the impact of future climate on millet production (Table 4.2), the study used the Soil-Water-Atmosphere-Plant (SWAP) model - an integrated physical simulation model for water, solute and heat transport in the saturated-unsaturated zone in relation to crop growth. The simulation of the reference period revealed average rainfall and crop yield of 976 mm and 1115 kg^{-1} respectively with a coefficient of variation (cv) of 30 percent for both parameters. The HADCM3 ('no regrets') results for average rainfall and yield for the near future were 882 mm and 1141 kg^{-1}, with a cv of 33 percent for both parameters, whilst for the distant future, average rainfall and yield were 510 mm and of 243 kg^{-1}, with cvs of 52 percent and 123 percent respectively.

Table 4.2: Impact of climate change on millet yields explored with the Crop-Soil Model for the two GCMs considered

	HADCM3		ECHAM4	
	Average ($kg\ ha^{-1}$)	**CV (percent)**	**Average ($kg\ ha^{-1}$)**	**CV (percent)**
Reference	1 115	30	923	23
Near Future (2010-2039)	1 141	33	1 046	24
Distant Future (2070-2099)	243	123	1 274	29

Note: Reference period for HADCM3 is 1961-1990, for ECHAM4 1990-1999.

In response to the projected negative impact of climate change on millet production, the SWAP model explored the 'no adaptation', introducing 'new crop variety', 'fertilizer application', 'irrigation', and 'supplemental irrigation' options (Table 4.3). With the exception of the 'no adaptation' option all the other options showed yield increases ranging from 9 to 37 percent as compared to the base case (1141 kg^{-1}). The cv was highest for the 'no adaptation' option and lowest for the 'irrigation' option. As a result the irrigation option was considered for the benefit-cost analysis, though in practice, irrigation of upland cereals is not the norm in the Gambia.

Table 4.3: Results of the adaptation strategies as explored with the model for the near future (2010-2039)

		Yield	
	Average (kg ha^{-1})	**Change (percent)**	**CV (percent)**
No adaptation	1141		33
Crop variety	1294	+13	32
Fertiliser	1517	+33	25
Irrigation	1563	+37	11
Supplemental irr.	1247	+9	30
Note: Change indicates the change in yield compared to the no adaptation; CV is the year-to-year Coefficient of Variation in yields.			

In the economic analysis, costs and benefits were assigned monetary values, which eliminated intangible costs and benefits that could not be expressed in monetary terms. Major considerations in the cost study included: (a) identification of water sources; (b) assessment of crop water requirements; (c) selection of irrigation method; and (d) costing of structural works, activities, and inputs, indispensable to irrigation water delivery. Annual costs were obtained by summing up investment, operation, maintenance, and replacement costs. On a percentage basis, operation and maintenance, and distribution costs represented the two largest components. For both surface and groundwater, and independent of scale, they account for 80 – 90 percent of total cost of irrigation using diesel-based water-lifting technologies. The corresponding value for solar pumping is 25 percent, whilst labour ccounts for 2 – 5 percent of costs.

Main conclusions for the Gambia study

The study evaluates the benefits of adaptation (i.e., irrigation) under current climate compared to no adaptation. Only direct benefits, which consist of increased farm production and income, are considered.

The detailed economic analysis shows that whilst preliminary results indicate substantial benefits from irrigation at a macro economic level, increased income from irrigation is not matched by costs incurred by farming households, suggesting the need for further policy measures to support irrigation. This is all the more relevant given the deteriorating economic situation, triggered mainly by low exports and increasing imports. Also, given the potential impacts of climate change and extreme weather on countries with surplus production, and the risk of those countries reverting to scarcity economics, especially in low production years, low GDP countries like Gambia are better of growing their own food than expecting to meet their demand from imports. Social impacts of re-vitalized agricultural production on employment generation, alleviation of poverty (increased income, improved nutrition of women and children), rural re-generation/development, etc., cannot be over-emphasized.

Capacity building outcomes and remaining needs

AIACC organized several well-timed workshops that added a new dimension to learning, experience and skills, introduced the project team to leading professionals in adaptation, and greatly improved the team's approach to the adaptation project. The workshops increased the capacity and ability of the project team to analyze technical issues; to appreciate the multi-disciplinary nature of adaptation and to work in this context; and to apply some of the techniques and skills learned. Case studies and presentations, given the diversity of participants and projects, were very enriching. These workshops proved to be a forum for new and innovative ideas, networking, information sharing and for exploring avenues for collaboration with other groups. We are now better able to supervise post-graduate students in adaptation, conduct more research in the area, monitor adaptation projects for other agencies, and even offer short courses on adaptation.

This project team has been able to develop a dynamic model, which uses runoff sources for all reservoirs and includes irrigated agricultural production. Further refinement of the models and constant updates are necessary to meaningfully explore policy options further. Second, affordability and availability of the latest software for GAMS would have helped find solutions in a much shorter time period and enabled the team to be better examine the area studied, to teach other members of the team about the packages used, to develop a broader range of scenarios, to work closely with other regional modelers, and to pass on the skill to others. The team now faces the important task of testing and applying the model developed to other river basins, and to further develop it as a standard tool that is easy to apply and interpret for estimating costs and benefits of adaptation to avoid climate change damages.

National communications, science-policy linkages and stakeholder engagement

The Department of Environment and Trade is South Africa's UNFCCC and GEF focal point, and hosts the National Committee on Climate Change (NCCC) meetings. The NCCC membership includes several government departments/ministries, some non-governmental organizations and interested researchers from various universities. As a member of NCCC, the Energy Research Centre attends and participates in regular meetings organized, and has been able to share research findings on adaptation.

The Department of Water Resources in The Gambia is responsible for the First National Communication (FNC), which is largely based on climate change studies undertaken by the National Climate Committee (NCC) under the chair of GCRU-DWR, and is the source of adaptation options/measures identified. The NCC brings together professionals from government, non-governmental organizations and private sector institutions.

GCRU-DWR in collaboration with UNEP has finalized its proposal for the implementation of the National Adaptation Program of Action (NAPA) under the auspices of the UNFCCC. All the adaptation options/measures that NAPA intends to examine originate from the First National Communication. It is expected that experience gained in the AIACC project would prove useful in the implementation of the NAPA.

Policy implications and future directions

Overall this study represents an important step in developing a close collaboration between scientists and water resources planners. Using the BRDSEM model, scientists can generate downscaled distributions of monthly average temperature and precipitation data and transform this into stochastic runoff so that it is more useful to planners. Water planners can therefore work with climate change data on essentially the same basis as with observed geophysical records, while accounting for inherent reliability problems in existing global and regional models to reproduce the 'historical' climate.

In order to further improve the BRDSEM model, it has been recommended it be modified to include characterization of the entire Boland Region in the Western Cape by means of: a) including runoff sources and dynamic water balances for all of the reservoirs in the area; and b) including linear programming representations for irrigated agricultural production in the lower Berg River Basin below the regional farms and north of the current study region.

Other recommendations include the need to conduct further research to estimate the parameters of sector-level monthly water demand and waterworks supply (cost) functions for the Metropolitan Cape Town Region. This would assist public and private sector policy makers and planners to address alternatives for balancing equity and efficiency considerations in urban water pricing. In addition, the BRDSEM model must be improved to include additional storage and non-storage capacity options for increasing water supplies and water use efficiency and reducing water losses in the basin, while accounting for the associated costs. There is also a need to improve the representation of water market transfers and include the costs of water market transactions. The current study does not take into account the effect of efficient water markets on the ownership of water rights and existing allocation of entitlements and neither does it include transactions costs associated with these transfers. Furthermore, broader range of policy options will have to be developed to blend efficient water markets with equity objectives in meeting the needs of the urban poor since the efficient market scenarios in this study led to high urban water prices and reduced consumption by all households under the high urban water demand and climate change scenarios.

In the case of the Gambia study, the most promising adaptation option(s) must be implemented and successive studies need to examine whether these adaptation strategies could be adopted through market forces; or whether there is a need for the government to impose them by means of subsidies or tax regulations; or whether bi-lateral aid would be required to minimize risks of food shortages.

4.9 Assessment of Impacts, Adaptation, and Vulnerability to Climate Change in North Africa: Food Production and Water Resources (AF 90)

Summary Information

Country: Egypt and Tunisia
Principal Investigator: A.F. Abou- Hadid
Administering Institution: Central Laboratory for Agriculture Climate (CLAC), Agriculture Researcher Center (ARC), Ministry of Agriculture and Land Reclamation, Egypt

Research problem and objectives

Agriculture represents the main land use in North Africa and is the principal water-consuming sector. Agricultural production in the region is expected to change rapidly due to technological advancements and social changes. Water demand for irrigation is expected to increase in all North African countries as a result. At the same time adverse effects of climate change are anticipated to affect agricultural activities and could lead to conflicts over resource use with other sectors. It is therefore important to define adaptation strategies that account for the possible deficit of water for irrigation in the future.

Adaptation to climate change in North Africa is a major issue from the perspective of food production, rural population stabilization, and distribution of water resources. The adaptive capacity is particularly challenged, as it comes in conjunction with high development pressure, increasing population, a water management system that is already regulating most of the available water resources, and agricultural systems that are often not adapted to local conditions.

The aim of this study is therefore to enhance scientific and technical capacity in countries in North Africa for: (1) Assessing current and future adaptive capacity and vulnerability of food production and water resources; (2) Enhancing current and future adaptive capacity; and (3) Synthesizing lessons learned. It also aims to evaluate the adaptation measures proposed by a range of stakeholders in North Africa derived from surveys of farmers and farmers' groups, and interviews with sub-national technical resource managers. Within this broad framework, the scientific objectives of the project are: (i) Stakeholder engagement (ii) Impacts detection (iii) Evaluation of adaptation methods and (iv) Linkages between climate information and scenarios and vulnerability.

Approach

The study was based on information exchange between the project team and stakeholders (Figure 4.4) to set definitions of adaptation measures, and to increase the capacity of stakeholders to understand climate-agriculture relationships. The stakeholders' measures were evaluated qualitatively by interviewing agricultural managers and quantitatively by using agricultural simulation models.

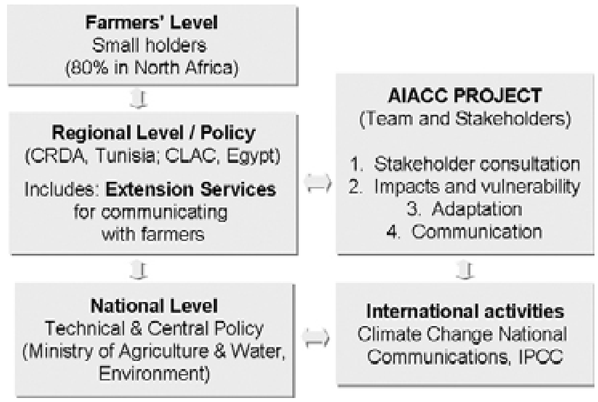


Figure 4.4: Linkages of the AIACC project team with stakeholders in North Africa

The project protocol consisted of five major steps: (i) Data collection, processing and analysis at the case study level to provide stakeholders with evidence of the current climate sensitivity of different sectors and groups (ii) Evaluation of stakeholder perception of impacts and their proposed adaptive methods (iii) Qualitative and/or quantitative evaluation of adaptation measures and their technical and social limitations (iv) Analysis of current and future vulnerabilities of the system and (v) Definition of the underlying causes of potential damage caused by climate change.

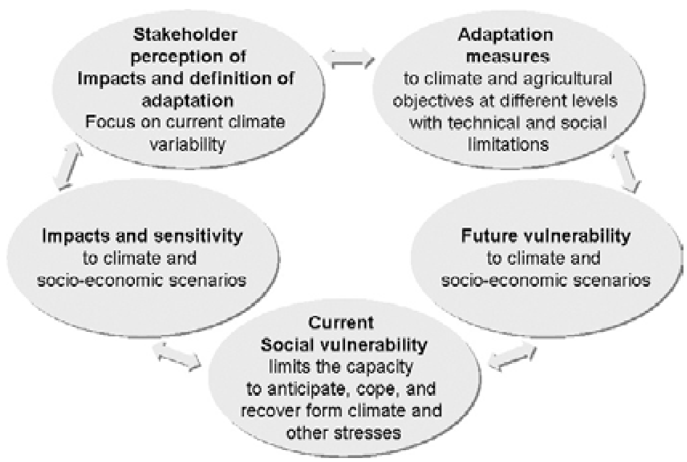


Figure 4.5: Outline of the study protocol

Two 'case studies' - Tunisia and Egypt - were selected to study the impact and the vulnerability of agriculture to climate change, and to evaluate adaptation strategies for a range of climate, agricultural, and socio-economic conditions found in North Africa. The study analyzed cereal and horticultural production. Rainfed and irrigated systems were evaluated to understand the interactions between climate, especially drought, its impacts, and the vulnerability of the system. Rainfed systems are particularly vulnerable to current climate variability and drought episodes. Irrigated systems are analyzed to evaluate the demand for water under changed climate conditions and to determine the value of additional irrigation as an adaptation alternative to climate change in North Africa.

The study in Egypt focused on the Nile Delta, represented by Sakha at Kafr El-Shikh Governorate, and Mersa Matrouh on the Northwest coast of Egypt. In Tunisia the study focused on the Kairouan area, Safax and Hendi Zitoun in the Central Region. The area is characterized by medium/low agriculture-production, and a high competition for land and water resources.

Climate and water availability was studied in North African countries of Tunisia, Morocco and Egypt as a variability analysis of rainfall, and the relation between rainfall variability and evapotranspiration. Agricultural production variability as a function of rainfall and irrigation is studied for cereal crops, tomatoes and olives.

Projected impacts on crop productivity in the project focal areas were assessed according to future conditions derived from the MAGICC/SCENGEN software, with input data from HadCM3 GCM and A1 and B2 SRES scenario experiments. The DSSAT (Decision Support System for Agrotechnology Transfer) simulation model was the main tool for the analysis of climate change impacts on crops production. DSSAT is software combining crop soil and weather databases and programs to manage them, with crop models and applications, to simulate multi-year outcomes of crop management strategies

Scientific findings

Egypt case study:

- There is an overall reduction in crop yields under climate change even when adaptation is taken into account.
- Under climate change conditions wheat variety, irrigation amount, sowing dates and water consumptive use (ET) would have to be changed according to the growing area to overcome the reduction in yield.
- In the study sample, farmers guided by their own experiences and/or with the help of the agricultural extension personnel applied some tactics and adaptation options to deal with changes in temperature or rainfall. The most common options were: changing crop sowing dates; use of heat tolerant varieties; increased frequency of irrigation; increased irrigation amounts; early morning or late evening application of irrigation and avoiding irrigation in the afternoon; intercropping; fruit mulching for vegetables; pesticide and fertilizer application management; underground and drainage water for irrigation; and change in crop varieties.

Tunisia case study:

- Among the research themes that produced results that can directly constitute adaptation methods are:

    - Increasing the agricultural area;
    - Management of water resources;
    - Improvement and the genetic selection of cultivars;
    - Improvement of techniques already used and the use of new techniques (fertilization, irrigation, etc.) that help to minimize the negative effect of climate variability and climate change.

- The involvement of the rural population concerned to attain these objectives remains essential. The participative approach is therefore necessary for the effective use of new technology. The aim should be to develop technologies adapted to the prevalent ecological and socio economic conditions, which can be attained by accounting for farmer's strategies in research development programs.

In general, climate is perceived by North African farmers as one of the major risks of agricultural production, but the magnitude of the risk is perceived as higher than the risk derived from empirical knowledge. Farmers do not recognize the importance of farming techniques for adaptive management and therefore their investments may not be completely productive.

There exists a range of adaptation measures but they vary in terms of levels of effectiveness, feasibility of adoption at the farmers' level, and social and environmental consequences (Table 4.4). Changes in crop variety, crop calendar, and irrigation amount and nitrogen fertilization emerged as the preferred options in this analysis. Combinations of the above options were also tested. Promoting education programs on water-saving practices and changes in crop choices was another adaptation option that resulted from this project investigation.

Table 4.4: Evaluation of the adaptation measures proposed by stakeholders in Egypt

Adaptation measure	**Potential value for improving production under climate change**	**Feasibility of adoption for the farmer**	**Environmental or social limitations to measure**
Changes in crop variety	Low	Easy Low cost	Easy Low to high cost
Changes in crop calendar	Low	Easy Low to very high cost	Easy and without cost
Changes in irrigation amount	High	Easy	Easy
Changes in nitrogen fertilization	Low	Easy Medium cost	High
Changes in crop variety, calendar, irrigation amount and nitrogen fertilization	High	Difficult High cost	High
Education on water-saving practices and changes in crop choices	High	High	Low

Only a limited number of farmers follow the advice of the extension services, which seems to be the key adaptation measure. The study concludes that the involvement of the rural population and extension services in capacity building programs is an essential adaptation measure, with information flows among and between these two groups of stakeholders.

Capacity building outcomes and remaining needs

Active participation in the AIACC Workshops and in other training activities contributed to the capacity building of the project investigation team. Relevant activities undertaken to increase awareness of climate change in the society were: a course of "Climate change and Agriculture" offered at the University of Al Azhar, Faculty of Agriculture, Department of ecology and bioagriculture and at Cairo University, Faculty of Science; a number of lectures and short courses offered for Egyptian and Arabian agricultural researchers; and special short courses offered for Egyptian undergraduate students as summer training courses. The project supported the thesis of highly qualified students; three of which are complete, and about seven are in the analyses and writing phase. Important experiences for most of the project investigators included the opportunity to work with stakeholder groups and working with climate models and crop simulation modules.

National communications, science-policy linkages and stakeholder engagement

The results of this project will be included in the 2nd National Communication of Egypt to the UNFCCC. This task is expected to begin in 2006. The principle investigator of this project, Mahmod Medany is contributing to the Fourth Assessment Report as a lead author in WG II, chapter 09 - Africa. The results from this project have also been presented by project investigators in a number of national level lectures, conferences and meetings, thus generating interactions between the project team and policymakers.

The project has enhanced stakeholder (farmers, extension service staff and agriculture advisors) engagement in defining adaptation measures, hence strengthening the relationship between the scientific team and the agricultural society. It has also helped the project team to identify stakeholders for participation in any further studies.

Policy implications and future directions

The results of this study and their dissemination among stakeholders provide the basis for planning for future national adaptation plans based on stakeholder opinions and inputs. At the same time the scientific community will continue to seek ways to find acceptable and efficient strategies to improve the relation between agricultural system and water resources, especially at the farm level. The Egyptian project team is now working on shaping the adaptation measures recommended by this project into a future agriculture adaptation plan or agenda to be linked with the long-term strategy of the Ministry of Agriculture. The aim is to improve crops production, reduce food scarcity, use natural resources in a sustainable way and improve the situation of the rural society.

4.10 Climate Change-Induced Vulnerability to Malaria and Cholera in the Lake Victoria Region (AF91)

Summary Information

Country: Kenya, Tanzania and Uganda
Principal Investigator: Shem O. Wandiga
Administering Institution: Kenya National Academy of Sciences, Nairobi, Kenya

Research problem and objectives

Malaria in tropical Africa is the leading cause of morbidity and mortality in the continent. In the last two decades the incidence of malaria has been aggravated by the resurgence of highland malaria epidemics, which hitherto had been rare. A close association between malaria epidemics and climate variability has been reported but not universally accepted. Similarly, the relationship between climate variability, intensity of disease mortality and morbidity coupled with socio-economic factors has been suggested but not proven.

The focus of this study is to improve the understanding of the relationship between climate change parameters (precipitation, hydrology and temperature) and the incidences of malaria and cholera in the Lake Victoria region (Kenya, Uganda and Tanzania).

Approach

The study began with the characterization of baseline temperature and precipitation variability and applied existing climate models and scenarios to estimate possible perturbations to these conditions. Hydrological characteristics and GIS layer maps of the study sites were constructed using historical precipitation data, river flows and surveyed socio-economic data. Time series analyses were used to correlate the relationship between climate, hydrology and disease incidences. In order to assess vulnerability of pilot groups, the teams used participatory methodologies and socioeconomic analysis tools, including retrospective and prospective data analysis to estimate the excess risk of malaria and cholera that may be attributable to future climate change.

The study team identified priority risk groups based on exposure potential, worked with pilot populations (representative of priority risk groups) to distinguish risk management strategies and selected preferred options to inform policy.

Scientific findings

The analyses of climate (temperature and precipitation) and hydrological data reveal the following:

The ranked Tmax and Tmin values indicate that high Tmax years are associated with El Niño occurrences, strongly suggesting that positive excursions in maximum temperature are significantly linked to ENSO.

Only two low Tmax years were observed in 1978 and 1985 in Kericho and in 1985 in Bukoba, suggesting that these occurrences are more related to variability in local conditions rather than to the larger scale synoptic weather patterns. Further the Tmin years point to possible influences by the strong El Niño's of 1982-83 and 1997-98 in Kabale and Bukoba areas, but not in the Kericho site. The Kericho site appears to have its own peculiar microclimate whose influence sometimes overrides the more regional temperature enhancing or cooling effects of El Niño and La Niña, respectively. The low Tmin years are invariably affected by milder El Niño's, and there is higher variability in local responses to such El Niño's amongst the three sites. This suggests that during mild El Niño's, the increased regional temperature effect is effectively muted, and also counteracted by increased and persistent widespread but heterogeneous cloudiness in the lake region. The year 1985 is interesting in that it is associated with low Tmax in Kericho area, low Tmin in Kabale area, and generally was a dry year as reflected by low flows in the rivers.

Evidence for a decadal cycle that influences climate (temperature) variability as indicated by the LOWESS (Locally Weighted Scatter plot Smooth) curve is supported by the synchronicity of the trend changes in the temperature records (maxima or minima) occurring in the Tmax (Kabale and Bukoba, minimum) and Tmin (Kericho, maximum; Bukoba, minimum), and by inflections in the strongly significant and tightly coupled LOWESS and linear regression curves for Kericho (Tmax) and Kabale (Tmin) in the years 1988/89. Such a decadal cycle has also been observed in the hydrological records for the Kericho site, which appears to have its most pronounced influence during the 'short rains' season, though it is also observed during the long rains season. Its variable influence around the lake basin is probably dictated by meso- to micro-scale differences in weather patterns. The influence of El Niño years and/or the effect of the Indian Ocean dipole reversal that also leads to high temperatures and precipitation in eastern Africa are clearly evidenced by the sharp positive excursions in temperature. The results concur with previous studies that determined an increasing trend in Tmin and Tmax over the majority of East Africa, with a few stations along Lake Victoria shoreline showing decreasing Tmin or 'no trend' characteristics. Locations along the lake have strong thermally induced meso-scale circulation, which together with local moisture sources can often modify large-scale circulation patterns, such as El Niño.

The ranked mean monthly cumulative precipitation data (1978-1999) show that in Kericho, wet years occur either during El Niño and La Niña years. While the strong El Niño of 1982-83 affected Kericho, the one of 1997-98 was not significantly wetter than other years in the period of analysis. In Kabale, wet years appear to be associated more with La Niña and El Niño, but more consistently with La Niña. This may indicate the much stronger coupling of Kabale area with Atlantic airstreams and a relatively weaker influence of the southwest Indian monsoon that appears to predominate in Kericho and Bukoba. In Bukoba, wet years are associated with El Niño and one occurrence of high rainfall has been observed during a non-El Niño/La Niña year (1985). The response to El Niño at this site is, however, more erratic and more widely spaced in time. Dry years in Kericho occur during El Niño and non-El Niño/La Niña years. In Kabale, dry years occur during El Niño, and there are single occurrences of such dry years during a La Niña and non-El Niño/La Niña year. In Bukoba, dry years are associated with non-El Niño/La Niña years, but it is significant that during the strong El Niño of 1982-83, Bukoba was generally dry, but experienced a 'normal' rainfall season in SOND (September, October, November and December).

While rainfall in East Africa tends to be above normal during ENSO years and rainfall deficits tend to occur in the ENSO (+1) years, the highlands often experience deficits during the boreal summer and the short-rain season of ENSO years and above normal rainfall during these months in the ENSO (+1) years. The observed heterogeneity in the rainfall patterns around Lake Victoria may be partly accounted for, to varying degrees, by a combination of factors such as differences in topography and aspect, changes in land use, the influence of Lake Victoria, and land-ocean interaction.

The communities in the highlands that have had less exposure to malaria are more vulnerable than their counterparts in the lowlands due to lack of immunity. However, the vulnerability of human health to climate variability is influenced by the coping and adaptive capacities of an individual or community. Surveys conducted among three communities in the East African highlands reveal that the interplay of poverty and other socio-economic variables have intensified the vulnerability of these communities to the impacts of malaria. Analyses of past climate (temperature and precipitation), hydrological and health data

(1961-2001), and socio-economic status of communities from the East African Highlands confirm the link between climate variability and the incidence and severity of malaria epidemics.

In the case of Cholera, epidemics have been recorded in history in the eastern African region, dating back to 1836. Each cholera epidemic incidence inflicts a high toll on human lives. However, the decline in cholera epidemic incidences between 1836 and 1970 caused a relaxation in public medical health preparedness until it resurfaced after 1970. Cholera is now endemic in the Lake Victoria basin, at least since the early 1970s (Rees, 2000), and in East Africa outbreaks have been reported to the World Health Organization (WHO) since 1972. Cholera epidemics within the East Africa region in recent decades occurred during the following years: 1978 (All), 1980 (All), 1981 (Kenya, Tanzania), 1982 (All), 1988 (Tanzania), 1991 (Tanzania, Uganda), 1992 (All), and 1997 (All). Thus, in 1998, more than 72 percent of the total global cholera cases were reported in Africa. The increase in cholera incidences is especially significant for the Lake Victoria region, which has one of the poorest populations of 30 million people and it is projected to increase to 53 million by 2025.

Climate in equatorial eastern Africa is complex and influenced by large scale tropical controls which include several major convergence zones superimposed upon regional factors associated with lakes, topography and the maritime influence. The inter-annual variability of rainfall is remarkably coherent throughout most of eastern Africa despite quite diverse climatic mean conditions. The largest portion of this variability is accounted for by the "short rains" season of October-December. Analyses of climate parameters (precipitation and temperatures) over the period 1978-2002 has been coupled with the analyses of hydrological characteristics of River Yala that serves as a suitable proxy for the Kisumu cholera study site. The other lowland sites had no gauged rivers. The results of these analyses have been correlated to the incidences of cholera epidemics and socio economic characteristics of the communities.

The results show that the seasonal trend analysis of high peak flows is closely associated with cholera epidemics, whose morbidity is several orders of magnitude more intense than the non-epidemic (hygienic) cholera episodes. The incidences of high cholera epidemics coincide with high flow peaks during El Niño years. Cholera epidemic coincidence with streamflow is not evident in the other non El Niño years. Furthermore, during the El Niño year the stream flow during the short rains season exceeds that in the long rains season. In addition, Tmax appears to influence the onset of cholera epidemics. In the years that cholera epidemics occurred (1982/3 and 1997/8), high above normal temperatures were recorded. Sustained high above normal temperatures during the first season, January, February and March (JFM) followed by a slight cooling in the second season, June, July and August (JJA) and above normal warming during the third season, September, October, November and December (SOND) triggers an outbreak of a cholera epidemic. Above normal precipitation and flooding alone without the above normal temperatures do not trigger outbreaks of cholera epidemics. The hygienic cholera outbreaks are associated with long rains season or short rains season when there is above normal rainfall and temperatures during the season but the casualties of such outbreaks are low compared to the cholera epidemic years.

Capacity building outcomes and remaining needs

From the experiences gained, the project encouraged the implementation of preferred adaptation strategies in communities to strengthen local coping capacity and monitor performance. The study incorporated capacity building in global change research in all of its activities, by training young scientists and engaging stakeholders and research scientists in the region.

This project resulted in the creation of a pool of climate change researchers in East Africa. The project trained the following persons: Two PhD students - Robert Kabumbuli and Faith Githui, both continuing their studies; one Fulbright Fellow - Michael Marshall; three Masters students - Rehema Sigalla (M.A. completed), Eugene Apindi (MSc ongoing) and Lydia Olaka (MSc ongoing); and two graduate assistants - Robinah Nanyunja and Timothy Baguma. In addition to the students, the capacities of the community leaders at each of the six study sites were improved with respect to knowledge of disease vulnerability and adaptation strategies.

National communications, science-policy linkages and stakeholder engagement

The principal investigator of this project, Professor Wandiga is the chair of the national communications committee on “Vulnerability and Adaptation to Climate Change” and the findings of the AF91 project will be contained in the report of this committee. Three of the project team members are also contributors to the IPCC Fourth Assessment Report.

Two National consultative meetings which brought together the research teams, government policy-makers (Ministries of Health, Environment and Natural Resources) and UNFCC communication contact person (s) were held in Kenya, Uganda and Tanzania. These meetings sought to create awareness about the project, obtain feedback from decision makers, seek access to health data and institutions, and finally to disseminate research findings and inform the development of adaptation strategies.

Project findings were also presented at a stakeholders’ workshop held in May 2005 to prepare a report on Kenya’s capacity needs to implement article 6, of the United Nations Framework Convention on Climate Change. Stakeholders drawn from local communities (such as teachers, women’s group members, NGOs, local administrative personnel, etc) were invited to meetings to obtain their feedback on research results and enlist their help in identifying risk groups, coping mechanisms and adaptation strategies for malaria and cholera epidemics. The participants also helped to identify specific target persons or organizations, which could help create awareness at the community level.

Policy implications and future directions

The research results have been factored into the national policies of the three East African countries’ malaria and cholera programs. Some of the immediate actions, which the Kenyan government has initiated include reducing the price of the insecticide treated nets (ITNs) to from US$ 3 to US$ 0.70 and with the same being available free of cost to all infants and pregnant mothers visiting government health institutions. The ITNs are used to protect against the bites of malaria transmitting mosquito vectors.

The Kenya team of the AF91 project in conjunction with the National Environmental Management Authority (NEMA) has initiated a follow-up action on adaptation to malaria and subsequently submitted a proposal to GEF entitled “Demonstration of efficacy, cost effectiveness and sustainability of alternatives for malaria control and development of adaptation mechanisms to climate change induced malarial episodes policy in selected Kenyan districts”. Based on the AF91 project results, a second project funded by the GEF and executed by the UNEP and African Centre for Technology Studies has been initiated to increase community resilience to drought.

4.11 Rural Households and Drought in the Sahel Region of West Africa: Vulnerability and Effective Adaptation Measures (AF92)

Summary Information

Country: Mali and Nigeria
Principal Investigator: Prof. A.A. Adepetu
Administering Institution: Center for Environmental Resources and Hazards Research, University of Jos, Nigeria

Research problem and objectives

This work on households, drought, and effective adaptation strategies in the West African Sahel was executed jointly by the University of Jos, Nigeria and The Institute of Rural Economy, Mali. This project’s study regions in Mali and Nigeria fall largely within the Sahelo-Saharan, Sahelian and Sahelo-Sudanian belts, subsequently referred to as ‘the Sahel’. This area covers about 30 percent of Nigeria and virtually the whole of Mali. Located on the southern edge of the Sahara desert, Mali has about 60 percent of its land area defined as hyper-arid or semi-arid. Variability is a major climatic feature in the West African Sahel. The Sahel experiences high variations in annual rainfall averages over decades. During the past century, several severe droughts have occurred including a long-lasting, extraordinary drought without precedence in the observed climatological record (Nicholson et al, 1988). The drought of 1968-73, for instance, affected no less than 16 countries. Although most people easily recall the drought of 1970-74, the year 1984 was a tragically strong marker in the climatological record of the Sudano-Sahelian region – it was the driest year on record (Walsh et al., 1988). These droughts caused untold human suffering, weakened the ecological equilibrium, and had a disastrous effect on agriculture and livestock production with consequences that are apparent even today.

Although droughts have been a recurring catastrophe in the Sahel region of West Africa, the IPCC Third Assessment Report notes a likely increase in continental drying and even greater drought risk in some areas (McCarthy et al, 2001). If this happens, the vulnerability of the Sahelians will increase and consequently aggravate social and environmental problems. We do not imply that drought is the sole cause of vulnerability in the region. It is, however, a major factor as it interacts with characteristically limited access to resources, wealth, technology, education, information, skills, and infrastructure and the region's poor management capabilities (McCarthy et al, 2001; Sen 1981).

While it is generally recognized that vulnerability varies spatially and temporally across different communities, the common perception among the public and policy-makers within the Sahel is that everyone is equally affected in vulnerable areas (Davies, 1996; Vogel, 1997). Despite substantive work that has already been done, this perception indicates that much remains unknown regarding vulnerabilities and adaptive capacities when the population is disaggregated into sub-groups. How people perceive droughts as well as their resource capability will affect their vulnerability and adaptive strategies. Although we may not be able to stop drought events, quantitative assessment of the adaptive capacity and vulnerability of various Sahelian groups to past and present drought disasters will form a basis for understanding future vulnerability and adaptation to drought hazards. This study asserts that semi-structured, open-ended data collection techniques can provide valuable new information. This is likely to be particularly true when long-standing cultural and economic differences among multiple ethnic groups produce different adaptation strategies to natural disasters, as is true of our setting.

This project mainly addressed the vulnerability of resource-poor households and groups. The impact of drought situations on resource-poor households and groups was hypothesized to be worse than the impact on others due to socio-cultural and economic positioning within the family and the community (Downing, 1997; Adger and Kelly, 1999). The study groups do not have the resources or even the access to resources that would help them cope effectively with drought situations. They are marginalized and are rarely given an important focus in drought and vulnerability studies.

The objectives of the project were to:

1. Identify the conditions that make certain groups in the Sahel particularly vulnerable to drought impacts through a systematic application of ethnographic methods and survey research. Knowledge concerning individual/household and institutional responses to drought is critical for capacity building to reduce vulnerability in the future.
2. Use data on past and present vulnerabilities and adaptations to develop empirical models of future vulnerabilities and adaptation to drought events.
3. Identify any gender differences in opportunities for and obstacles to adaptation among different groups that are at risk in the Sahel region.
4. Provide a multi-disciplinary baseline database where change, adaptive strategies, and environmental processes can be monitored.

The research sought to address the following questions:

- Who are the most vulnerable groups, and what shapes their vulnerability in the face of climate variability and change?
- What shapes the exposure to and ability of certain groups to rebound from drought hazards?

- What are the similarities and differences between present day vulnerability and adaptation and future vulnerability and adaptation to drought impacts?
- How does institutional capacity influence the capacity of affected individuals and households to cope with/adapt to droughts and reduce vulnerability?
- Will adaptive capacities change in the future? If so, how?

While the general focus of this research was resource-poor groups, special attention was paid to women who, because of socio-cultural values and economic positioning within the household and the community, are likely to be more vulnerable to the impacts of climate change.

Approach

This project defined vulnerability in terms of the capacity of individuals and social groups in the Sahel to respond to – that is, to cope with, recover from, or adapt to – any drought-related stress placed on their livelihood. To achieve the objectives of the project, the study team proposed the use of a hybrid methodology (Figure 4.6) that derives from a vulnerability/risk framework, after Downing (1992) and Jones (2001). It focuses on *current* vulnerability, *risk* of present and future climatic variations, and *responses* to reduce present vulnerability and improve resiliency to future risks. The stakeholder is at the center of the research. This was very important in the project, as people in the Sahel have developed indigenous knowledge systems that have enabled them to cope, so far, with drought. In addition, some stakeholders have various levels of experience in developing and implementing projects of this nature in the Sahel.

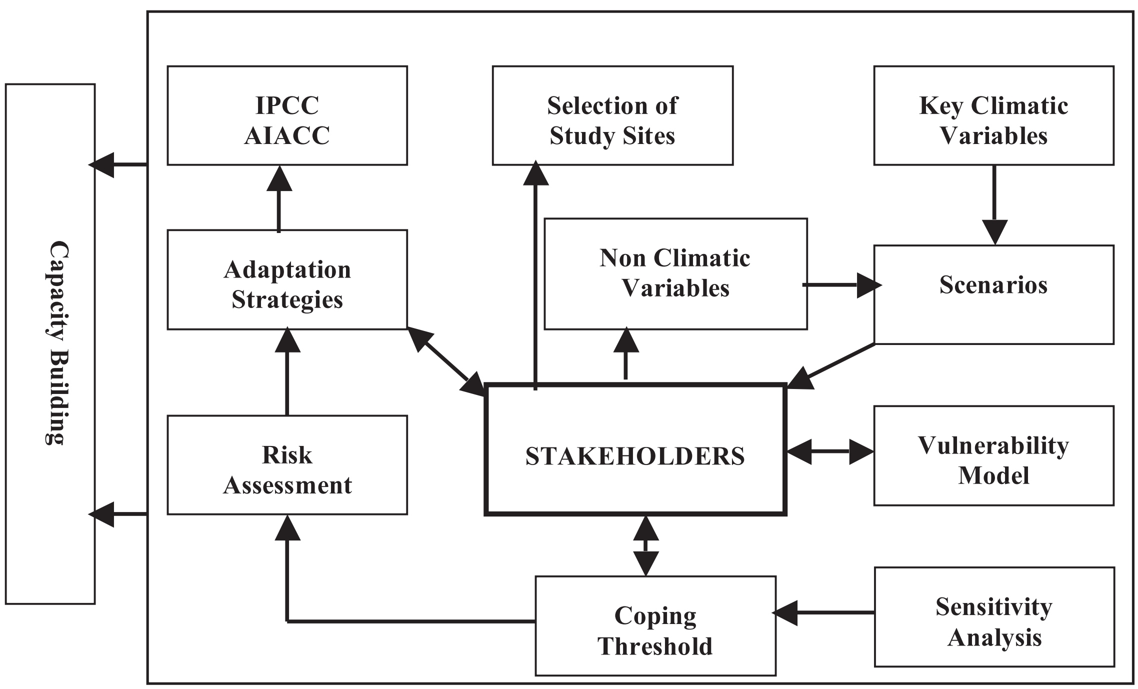


Figure 4.6: Project framework

The methodology used in this study combined various conventional tools such as Rural Rapid Appraisal, the farming system approach at community and farmer levels, questionnaire surveys, desk research, and focus group discussions. Climatic and non-climatic data were collected from relevant institutions in Nigeria and Mali. Climatic data included surface air temperature, precipitation, the number of rain days, and the onset and cessation of rain. Non-climatic data included socio-economic and environmental data.

The fieldwork for data collection started with a reconnaissance survey of the project area to identify communities that would be included in the study. Research and field assistants were recruited and trained on appropriate methods of data collection. The collection of qualitative data was an important part of the methodology. It involved semi-directed interviews with farm households and focus groups. Among the various topics covered in the semi-directed interviews were the food security strategies of farm households, the farming systems and women's activities within farm households, the main constraints of livelihood systems, and farmers' access to resources (cropland, livestock, labour and markets). The analyses combined quantitative and qualitative assessment approaches.

Scientific findings

Socio-ecological systems in Nigeria and Mali are vulnerable to climate variability and change. Vulnerable farm households were found in most rural livelihood systems. Major vulnerabilities identified by the local populations include: shortage of water for animals, insufficient food for people, conflicts/insecurity, crop failure, animal diseases, human diseases, limited land for cultivation, shortage of crops for cultivation, lack of employment, low prices for animals, insufficient pasture for animals, and shortage of water for domestic use. Most of these vulnerabilities can be traced to the impacts of climate variability.

Variables that influenced this vulnerability include household factors such as household size, availability of labour, health of household members, size of land cultivated, proportion of land under irrigation, size of cattle holdings, education of household members, combined income of household members from all sources, and gender of household head. Other factors include distance to market, proximity to motorable road, membership in community organizations, availability of storage facilities, and interaction with extension workers.

Incidence of poverty is high in both countries but higher in Mali. Absolute numbers of poor are relatively high as well. A large proportion of the sampled population depends on non-farm income to augment their earnings from agriculture. Growth potential is modest and presents important challenges, but a sufficient range of technologies is available to warrant a sustainable increase in the productivity of all systems. Some technologies (both hard and soft) that are utilized to reduce the adverse impacts of droughts include rainwater harvesting, use of drought-resistant crops, local farm management techniques, adjustment of planting dates, and the development of indigenous early warning systems.

Capacity building outcomes and remaining needs

This study team did not set out from the onset believing that it knew much better than the local populations who have lived in equilibrium with the environment for centuries and who have adapted to climate variabilities larger than the changes predicted by most climate models. Rather, we sought to partner with them to understand how they have dealt with past and current vulnerabilities to be able to devise effective adaptation strategies that will reduce their vulnerabilities to future climate change. We do not endorse, however, that all indigenous adaptation strategies are effective and sustainable. Rather, a first step to designing sustainable strategies is to understand what the stakeholders are currently doing and why they do it the way that they do.

Capacity building for this project was implemented at two levels. Informal capacity building efforts recruited local populations and trained them to administer the questionnaires. As part of the training, they were introduced to concepts such as global warming and how to carry out climate change assessments. This was complimented by two sets of workshops. First, a sensitization workshop encouraged local participants to adopt natural resource management strategies that would have minimal harmful impacts on the environment. The aim of the second workshop was to present and discuss the results of the project's assessment. A second level of capacity building was formal training of students at both the graduate and undergraduate level at the University of Jos. Four undergraduate students and three M.Sc, students wrote their theses on the project. Two Ph.D. students are at various stages of completing their dissertations on the project.

There are still areas of need in terms of capacity building. Neither of the project's executing institutions have strong computing facilities to support engagement in climate assessments and modeling. It would be a good opportunity to establish a regional node for climate assessment in one of these institutions that would train West African scientists on climate assessments. Second, this study mainly considered current vulnerability, without much attention to future vulnerability and future adaptive capacity. This was largely due to the fact that there was limited capacity to build socioeconomic scenarios for the region. There is a need to train more scientists and equip them with the tools to develop socioeconomic scenarios so that future vulnerabilities to climate change in the Sahel can be assessed.

National communications, science-policy linkages and stakeholder engagement

The project and members of the project team have been involved in the national communications programmes of both countries. In Nigeria, the project forms the basis for the country's second National Communication to the UNFCCC that is in progress. Stakeholders have also been involved in the project. For instance, the national meteorological agencies of both countries are partners in the project, as well as several NGOs. The Mali team has also been involved in the national adaptation programmes of action (NAPA) process. The team has provided support for developing participatory and collaborative adaptation in partnership with rural communities and other institutions. They have been involved in several community level dialogues on climate change, have engaged in building the capacity of rural communities in vulnerability assessment and climate change related issues, and have developed community action programmes on adaptation to climate change.

Policy implications and future directions

Adaptive capacity

In the Sahel, there are current limitations in adaptive capacity to reduce the vulnerability of farm households to climate change, including extreme events. As demonstrated by recent climate experiences, capacity for managing climate risks, including seasonal forecasting, early warning systems, disaster preparedness, and relief, needs to be improved for the region as a whole. In most farming systems, adaptation has not been implemented to account for inter-annual or inter-seasonal variations in current climate. The study has revealed that the adaptive capacity of vulnerable populations is inadequate for overcoming barriers and for adopting policies and measures, even if relevant information is available.

Planning and programmes

At the national and regional levels, many plans and programmes do not address climate variability and may inadvertently increase climate vulnerability. Although both Mali and Nigeria have an environment action plan, lack of plan enforcement may increase climate vulnerability. In addition, many public sectors are undergoing widespread privatization and decentralization. In most cases, vulnerable populations rely on autonomous adaptation strategies. They don't have the resources to implement planned adaptations strategies. Within the national political agenda, development strategies generally do not address climate vulnerabilities or consider adaptation responses. This policy context has significant implications for targeting the right type of stakeholders and ensuring that the policies and measures identified can be adopted.

Social, economic and environmental conditions

The deterioration of social, economic and environmental conditions increases the risks associated with climate variability and change. Given that a significant proportion of the population lives in places of high risk, loss of human lives, housing, and other infrastructure is common. Climatic disasters can, in only a matter of days, erase years of economic development and gains in the quality of life and have resulted in a growing demand for international grants and loans for emergencies and long-term reconstruction. The effects of climate change on the national economy and official development assistance have not been considered in most vulnerability assessments.

4.12 References

Adger, N. and M. Kelly 1999: "Social Vulnerability to Climate Change and the Architecture of Entitlements." Mitigation and Adaptation Strategies for Global Change 4: 253 – 266.

Callaway, John. M., L. Ringius, and L. Ness. 1998. 'Adaptation Costs: A Framework and Methods' in Christensen, J. and J. Sathaye (eds*.), Mitigation and Adaptation Cost Assessment Concepts, Methods and Appropriate Use*. UNEP Collaborating Centre on Energy and Environment, Risø National Laboratory, Roskilde, DK.

Callaway, John M. 2004a. 'Adaptation benefits and costs: are they important in the global policy picture and how can we estimate them,' *Global Environmental Change* 14:273-282.

Callaway, John M. 2004b. 'Chapter 4: The benefits and costs of adapting to climate variability and Change' in OECD, *The Benefits and Costs of Climate Change Policies: Analytical and Framework Issues*. OECD, Paris, France.

Downing, T. E., L. Ringius, M. Hulme and D. Waughray. 1997. 'Adapting to climate change in Africa.' *Mitigation and Adaptation Strategies for Global Change* 2: 19-44.

Hurd, B. J. Callaway, P. Kirshen, and J. Smith. 1999. 'Economic Effects of Climate Change on US Water Resources' in Mendelsohn, R. and J. Neumann (eds.), *The Impacts of Climate Change on the US Economy*. Cambridge University Press, Cambridge, UK.

Hurd Brian H., Mac Callaway, Joel Smith, and Paul Kirshen. 2004. Climatic Change and US Water Resources: From Modeled Watershed Impacts to National Estimates. *Journal of the American Water Resources Association* 2: 130-148.

IPCC. 2001. 'Summary for Policymakers'. In J. Houghton, Y. Ding, D. Griggs, M. Noguer, P. van der Linden and D. Xiaosu (eds), *Climate Change 2001: The Scientific Basis.* Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK and New York, USA.

McCarthy, J., O. Canziani, N. Leary, D. Dokken, and K. White (eds). 2001. *Climate Change 2001: Impacts, Adaptation and Vulnerability.* Contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, UK and New York, USA.

Nicholson, S.E. 2001. 'Climatic and environmental change in Africa during the last two centuries'. *Clim. Res.* 17:124–144.

Kiker, G. 2000. South African Country Study on Climate Change, Synthesis Report for the Vulnerability and Adaptation Assessment Sector, Pretoria, South Africa.
Available: http://www.sanbi.org/countrystudy/main.htm

Rees, P.H. 2000. Editorial–Cholera. *East Afr. Med. J.* 77:345–346.

5 Climate change assessments in Asia

In Asia, five projects were undertaken, largely focusing on issues related to climate change impacts and adaptation for agriculture, land-use and water resources. These include one project addressing the vulnerability of the grassland ecosystems and the livestock sector in Mongolia; two projects addressing issues pertaining to water resources and agriculture in various Southeast Asian countries; one project on coconut and tea plantations in Sri Lanka; and one project on agriculture and water resources in Western China. Short summaries describing the findings from individual projects are provided below.

* Details about the scientific literature referenced in the project summaries below are available in the final project reports accessible at: http://www.aiaccproject.org/Final Reports/final_reports.html

5.1 Climate Change Vulnerability and Adaptation in the Livestock Sector of Mongolia (AS06)

Summary Information

Country: Mongolia
Principal Investigator: Punsalmaa Batima
Administering Institution: Institute of Meteorology and Hydrology, Ulaanbaatar, Mongolia

Research problem and objectives

In Mongolia the risk of climate change and/or extreme climatic events such as drought and *dzud* have dramatic impacts on its economy and natural systems. Agriculture, livestock, grassland ecosystem, and water resources are among the most vulnerable systems. Resilience and adaptive capacity of traditional networks and land use systems to cope with climate variability/extremes are weakening, while frequency and magnitude of climate variability and land use intensity are on the rise. These factors enhance the vulnerability of Mongolian rangelands, livestock and people.

Taking into account the country's specific circumstances in terms of natural resources and agricultural development, the overall objective of this project was therefore to determine the potential impacts of climate change and assess the vulnerability of and adaptation options for rangeland and livestock in Mongolia. Priority was given to the study of interactions between the climate and grassland and pastoral systems, and integration of social factors in this analysis. The scientific understanding of the impact of past climate change on grassland ecosystems and the livestock sector, and assessment of their vulnerability and adaptation were also the focus of our study.

Approach

Different approaches such as analytical analysis of existing long-term plant dynamics and animal and climate databases; ecosystem animal modeling; remote sensing and GIS technology; and field and participatory surveys were used for the investigation of climate change effects on grassland and livestock structure and function.

Scientific findings

The livestock sector is the major economic sector of Mongolia. Climate change is expected to impact all aspects of this sector - from the natural grasslands to the competitiveness of the livestock economic capacity; and ultimately it could also alter the pattern of individual and community lifestyles in Mongolia. Key findings of this research are summarized bellow.

The observed climate

Observations from 60 sites distributed across the country show that the Mongolian climate has already changed significantly. Annual mean temperatures have risen by 1.8°C between 1940 and 2003, with warming most pronounced in winter. The heat wave duration has increased by 8-18 days, depending on the geography and the cold wave duration has shortened by 13 days. Annual precipitation changes are quite variable, decreasing at one site and increasing at a site nearby. Seasonally, autumn and winter precipitation has increased while spring and summer precipitation has decreased. Spatially, annual precipitation decreased in the central region and increased in the western part and in the most south-eastern part of the country. Statistically, there were no significant changes in the maximum number of consecutive dry days on an average. Potential evapotranspiration has increased by 7-12 percent over the last 60 years.

The future climate

Projections of future climate were obtained from the IPCC's SRES (Special Report on Emissions Scenarios) scenario runs performed with three coupled General Circulation Models (GCMs), the HadCM3, ECHAM3, and CSIRO Mk2. For all the models, the response to the middle forcing scenarios A2 and B2 was referenced and future climate change was presented for three 30-year time slices centered on the 2020s, 2050s, and 2080s, each relative to the baseline period 1961-90. Consistency with historical data for the baseline period was also established. Among the three models, the HadCM3 provided the closest match to observed data.

The climate models suggest that: a) The rate of future winter warming in Mongolia is projected to vary from 0.9ºC to 8.7ºC, while the summer temperature increase is projected to vary from 1.3ºC to 8.6ºC; b) Winter precipitation will likely increase by 12.6 - 119.4 percent while summer rainfall could vary from a 2.5 percent decrease to 11.3 percent increase; and c) In contrast to the small increase in summer rainfall a much higher increase in evapotranspiration by 13 - 90.9 percent is expected, depending on ecosystem regions. In general the HadCM3 scenarios project dry and hot summers and milder winters with more snow.

Natural environmental impacts

The climate change studies conducted in Mongolia concluded that global warming would have a significant impact on natural zones, water resources, snow cover and permafrost.

<u>Water resources:</u> Clear changes in the dates of autumn and spring ice phenology occurrence have been observed with a shift in freeze-up and break-up dates ranging from three days to a month, depending upon geographical location. Changes in ice phenology dates correspond to an increase in air temperatures of autumn and spring months, when river ice processes take place. Ice cover duration has shortened and ice thickness at rivers and lakes has decreased. No clear decreasing and increasing trend in river runoff over the past 60 years has been observed. A one to three weeks advance in spring snowmelt runoff since the 1980s has been observed. Results of the HadCM3 and CSIRO-Mk2b project a slight decrease in river runoff due to a decrease in summer precipitation accompanied by increasing temperature. The impact of precipitation changes on river flow are expected to be substantially greater than the impact of temperature fluctuations - for each ^{o}C temperature increase; at least a 2 percent decrease of annual flow is projected.

<u>Snow cover:</u> The climate of Mongolia is cold, with an annual mean temperature of minus 0.8°C. Clear skies in winter due to high anticyclone dominance over Mongolia result in less snowfall. Snow contributes less than 20 percent to the total annual precipitation. About 62 percent of the country's territory is covered by snow for more than 50 days in a year, the actual duration varying as per geographical location. Snow plays an important role in livestock herding, since it serves as a water resource for animals in winter but too much snowfall has an adverse effect.

The findings of this study show that snow cover disappearance appears to have shifted by about 3-10 days earlier since 1981 and is projected to shift by 20 days in 2080 relative to current levels. No clear changes were observed in the extent of snow cover but future declines of 27 to 56 percent have been projected for 2020-2080. The area of continuous snow cover with a duration of more than 140 days is expected to decline while the area of snow cover with a duration of 120-140 days is expected to increase.

Frozen ground: Frozen ground characterizes permafrost, seasonally frozen ground and surface soil freeze. The permafrost region occupies about 63 percent of the total territory of Mongolia and may be classified into categories: continuous, discontinuous, widespread, rarespread, sporadic, and seasonal. It has been observed that permafrost temperature has increased from 0.05°C to 0.15°C since the 1970s and permafrost phenomena such as melting mounds, thermokarst, and solifluction occur more frequently and extensively. The thickness of seasonally frozen ground has decreased by 10-20 cm over the last 30 years; 2-6 day delays have been observed in surface soil freeze in autumn; and a 2-6 day advance in the date of the spring thaw has been recorded.

Ecological and economic impacts

Pasture

About 80 percent of Mongolia's total land area, or 127,307,000 hectares are used for pasture. Pasture growth begins in late April and biomass peak is usually reached in August. Mongolian livestock obtains over 90 percent of its annual feed intake from annual pastures. During winter, when the grass dries off and its quality deteriorates, the animals take only 40-60 percent of their daily feed requirements. The four main pasture ecological zones i.e. high mountains, forest-steppe, steppe and desert and pasture yields are highly sensitive to climate and weather conditions. It has been observed that the peak of pasture biomass has declined by 20 to 30 percent over the past 40 years and a clear decline in the Normalized Difference Vegetation Index (NDVI) in 69 percent of the country's territory for the last 20 years has been noted. In addition an overall decline in fodder production and a decrease in high nutrient plants with a dominance of low nutrient plants in pasture communities have been observed. It is projected that pasture biomass will decrease in the forest-steppe and steppe (the HadCM3 projects a decrease from 0.6 to 37.2 percent between 2020-2080) and increase in the high mountains and desert.

An effort was also made to analyze the effects of climate change on ecosystem zones in Mongolia using the CENTURY model to determine the current Net primary Productivity (NPP) and Aridity Index that corresponds to each natural zone. It is determined that enhanced dryness resulting from an increase in air temperature would lead to a shift in the boundaries of current ecological regions to the north of the country. In particular, the desert area is expected to extend to the north by 2080.

Livestock

The pastoral livestock sector directly engages half of the Mongolian population and provides food and fibre to the other half. Livestock and livestock processed exports amount to about one- third of foreign exchange earnings. Apart from providing major nutritional sources, livestock is widely bartered in exchange for all kinds of non-animal products. Mongolia's development is highly dependent on pastoralism. Mongolian rangeland sustains livestock activities, subsistence farming, and is a key factor in the economy of the country.

Climatic conditions that prevent animal grazing are projected to increase in both summer and winter seasons. Unfavorable conditions in summer are expected to increase in the eastern and central steppe, while unfavorable conditions in winter would increase in the northwestern mountainous region. Observed data show a decline in the average weight of sheep, goat and cattle by an average of 4 kg, 2 kg, and 10 kg, respectively, from 1980 to 2001 (Bayarbaatar et al, 2005). Sheep wool productivity has decreased by more than 8 percent, while cashmere productivity has decreased by about 2 percent over the last 20 years. Post-climate change summer conditions are projected to have a greater adverse impact on animals than the changed winter conditions. Summer ewe live-weight is likely to decrease by about 50 percent, while winter ewe live-weight is expected to decrease by 15 percent by 2080.

Vulnerability

The frequency and magnitude of climate variability and extremes and the risk of unexpected changes in nature and environment are expected to increase with changes in climate. Since more than 80 percent of the county's territory has been defined as highly vulnerable to climate extremes, the increased incidence of drought and dzud pose key risks for livestock. The extent of unsuitable grazing areas is projected to increase from the current 40 percent to about 70 percent by 2050, and 80 percent by 2080 due to climatic impacts. Projected drought index trends estimated by HadCM3 scenarios are high enough to double the severity of these extremes by 2080. In the absence of adaptation measures, animal mortality is expected to reach about 12 percent by 2020, 18-20 percent by 2050 and 40-60 percent by 2080.

Drought: Over the last 60 years a 95 percent increase in droughts has been observed with a rapidly worsening situation over the last decade. The worst droughts Mongolia experienced was in the consecutive summers of 1999, 2000, 2001, and 2002, which affected 50-70 percent of the territory. During the past four years, about 3,000 water sources including 680 rivers and 760 lakes have dried up. Such environmental degradation in turn has affected the primary productivity of vegetations/plants and water resources, which support livestock as well as human populations. A dry summer or prolonged drought results in the scarcity of pasture plants, palatable species, water and grass. It thus prevents animals from building sufficient strength and energy to survive through winter and therefore animal mortality is high. Drought also prevents herders from preparing hay and other supplementary feed for animals and dairy products for themselves.

Dzud: The *dzud* is a very complex and long-lasting natural phenomenon characterized by sudden spurts of heavy snowfall, long-lasting or frequent snowfall, extremely low temperatures, or drifting windstorms that reduces or prevents access to grazing. In other words, the term *dzud* can be described as 'livestock famine', and the widespread death of animals because of hunger, freezing and exhaustion. This negatively impacts the food security of livestock and represents a high risk to humans in the affected areas. There are several forms of *dzud*, depending on the characteristics, contributing factors and causes: *Tsagaan* (white); *khar* (black); *tumer* (iron); *khuiten* (cold); and *khavsarcan* (combined).

Mongolia experienced severe *dzud* in the years 1944-45, 1967-68, 1978-79 and 1999-2002 during which an abnormally high number of animals were killed. During 1999-2002 Mongolia experienced a series of annual *dzud* episodes, which caused the death of more than 12 million livestock and 12,000 herder families lost all their animals. The worst *dzud* in the last 30 years occurred in 1999-2000 when herders lost more than 25 percent of their livestock, 10 times higher than the normal year loss (*Mongolian Statistical Yearbook*, 2001) and international relief assistance had to be relied upon. Mongolia's gross agricultural output in 2003 decreased by 40 percent compared to that in 1999 and its contribution to the national gross domestic product (GDP) decreased from 38 percent to 20 percent (*Mongolian Statistical Yearbook*, 2003).

Adaptation

The AIACC study in Mongolia concluded that increased extremes resulting from climate change are a significant barrier to livestock sector development and this impediment could grow significantly over the next 80 years. It is, therefore, essential to recognize and maximize the potential linkages between adaptation in the livestock sector and development of the country. Mongolian pastoral livestock production system has three primary components: (a) natural resources, including the physical and biological environment or primary resources and climatic conditions; (b) livestock, including the bio-capacity of processing and converting feeds to products (i.e., milk, meat, fiber) at a rate sufficient to meet animal needs and provide a surplus for human needs; and (c) herders who manage livestock production. Therefore, the identification of adaptation options (Table 5.1) first focused on conservation of natural resources; followed by strengthening animal bio-capacity to cope with the adverse impacts of climate change; and finally, better management practices by herders to to enhance the livelihood of Mongolia's rural community.

The selected adaptation measures relate to two types of impacts of climate change: *(a)* gradual long-term changes (degradation of quantity and quality of pasture) that focus on changing the current trends; and *(b)* changes in the frequency and intensity of extreme events (drought and *dzud*), which mainly focus on increasing the efficiency and effectiveness of current measures. Sustainable pasture management aimed at increasing livestock productivity, as well as the high-level maintenance of pastures is the strategy of choice for maintaining adequate food and water supply to ensure animal survival and productivity. Adaptation measures to reduce the impact of long-term changes on the livestock sector largely focus on improved pasture yield including the revival of traditional pasture management, which involves the use of one pasture only for the length of one season; restoration of degraded pasture including reforestation of flood plains and increased vegetation cover; expansion/rehabilitation of pasture water supply; development of irrigated pasture; modifying the schedule of grazing and others. It is also important that the livestock do not exceed the carrying capacity of the pasture

Table 5.1: Adaptation measures

Vulnerability	**Mass death of livestock, increased poverty in rural area and overall decline in national economy of Mongolia**							
Climate drivers	**Drought, harsh winter (locally known as *dzud*) extremely low temperature, high snowfall, snowstorms**							
		Evaluation criteria						
Adaptation objective	Adaptation measures	current capacity	opportunity	effectiveness	benefits	cost	barrier	Expected results
Improved integrated pasture management	Improve grazing management	M	H	H	H	L	S&m	Increased conservation of nature and ecosystem
	Introduce cultivated pasture	L	M	H	H	H	F	Reduced dependency on climate, increased opportunity to develop intensive livestock industry
	Improve pasture yield	L	M	M	H	H	T&F	Increased feed, reduced vulnerability to drought and *dzud.*
	Improve pasture water supply	L	H	H	H	H	T&F	Better use of pasture and stock survival, ecosystem conservation and rural development.
	Legislate possession of pasture	M	M	M	M	L	S&m	Effective development of cultivated pasture
	Introduce taxation of pasture	L	M	M	M	L	S	Increased conservation of nature and ecosystem
	Livestock population control according to the pasture capacity	M	M	M	M	H	S	Increased conservation of nature and ecosystem
Increased strengthening of animal bio-capacity	Improve shelter for animals	M	H	H	M	M	F	Reduced vulnerability to climate extremes not only dzud but also snow and wind surges and others
	Increased supplementary feed	M	H	H	H	M	N&F	Reduced vulnerability to and minimize loss of animals during drought/*dzud*,
	Improve per animal productivity	L	H	H	H	H	T&F	Increased income and livelihood
	Introduce genetic engineering	L	H	H	H	M	T&F	Increased productivity and breeds
	Improve veterinary services	M	H	H	H	H	T&F	Decreased disease
	Introduce high productive cross breeds	L	H	H	H	H	T&F	Increased animal quality and income, reduced vulnerability
Enhanced livelihood of rural	Promote collective communities	M	H	M	H	M	S&m	Increased capacity to cope with climate driving disasters

community								and increased livelihood
	Develop/transfer new technologies	M	H	H	H	H	T&F	Increased opportunity to develop intensive livestock industry
	Expand access to credit and generate alternative income	L	H	M	H	H	m	Increased financial capacity
	Expand the supply of renewable energy applications to herders	M	H	H	H	M	T&F	Increased livelihood
	Promote and support the establishment of different kind of enterprises	L	M	M	H	H	T&F	The base to develop intensive livestock industry
	Establish insurance system of animals	L	M	M	M	H	T&F	Reduced vulnerability to climate extremes and decreased poverty
	Establish risk fund	L	H	M	H	H	F&m	Reduced vulnerability to climate extremes and decreased poverty
	Prepare educated herders	L	M	M	H	M	S	Increased opportunity to develop intensive livestock industry
	Training of young herders	H	H	M	H	M	L	Increased capacity
Increased food security and supply	Expand dairy and meat farms close to big cities to meet the demand of milk and other dairy products	M	H	H	H	H	T&F	Increased opportunity to develop intensive livestock industry
	Promote and expand other food supply farms / egg, vegetables /	M	H	H	H	H	T&F	
Climate Change study	Establish climate change monitoring stations	H	H	H	H	H	T&F	Increased scientific knowledge in climate change studies
	Improve forecasting system of extreme events	H	H	H	H	H	T&F	
Note: H-high, M-medium, L-low, F-financial, T-technical, S-social, m-management,								

Capacity building outcomes and remaining needs

Considerable progress in capacity building in following areas has been made:

- Improved data collection and management
- Reduced data gaps in key activities
- National information exchange network established

- Multi-disciplinary team of scientists created
- Permanent climate-animal observation site established

National communications, science-policy linkages and stakeholder engagement

The Mongolian ministry that deals with climate change and environmental issues is the Ministry of Nature and Environment (MNE). The National Agency for Meteorology, Hydrology and Environment Monitoring (NAMHEM), which is directly under the responsibility of the MNE, is responsible for coordinating the work under the NCCSAP. The Agency has been designated by the government as the lead agency for climate change issues in the country. The Institute of Meteorology and Hydrology (IMH), which is under the responsibility of the NAMHEM, conducts climate change research and includes departments dealing with agricultural climate and water resources management and others. The final, annual, and semi-annual reports and all other outcomes of the project have been submitted to the MNE, NAMHEM and IMH. The MNE is also responsible for the preparation of Mongolia's second national communication and the findings from this project will provide direct inputs to this document.

In addition, information on strategies to reduce the vulnerability to climatic impacts were shared with local stakeholders i.e. herders and administrators, and their inputs were also obtained. Policies to build adaptive capacity options in the context of development, sustainability and equity were also evaluated in collaboration with all stakeholders.

Policy implications and future directions

This project has largely contributed to the implementation of climate change response activities identified in the Mongolia National Action Program on Climate Change that has been developed in accordance with the UNFCCC, and approved in July 2000 by the Government. It has also assisted in the preparation of the second national communication to the UNFCCC.

The implementation this project has helped to initiate and strengthen a climate change dialogue process among governmental, non-governmental, academic, business, and grassroots sector, which has helped to foster understanding of climate change issues such as vulnerability and adaptation and linkages with sustainable development strategies at various sectoral levels. An integrated adaptation-development policy is envisioned for the future given that adaptation is a development issue. A set of adaptation actions has been suggested, which would reap development benefits regardless of the impacts of climate change.

5.2 Vulnerability to Climate Change Related Water Resource Changes and Extreme Hydrological Events in Southeast Asia (AS07)

Summary Information

Country: Thailand, Lao PDR, Viet Nam
Principal Investigator: Anond Snidvongs
Administering Institution: Southeast Asia START Regional Center, Bangkok, Thailand

Research problem and objectives

Research problems:

- What are the impacts of climate change on the hydrological regime and fresh water resources in Mekong River Basin?
- What are the impacts of climate change on rain-fed rice productivity in Mekong River Basin?
- How would rain-fed farmers in the region be vulnerable to the impacts of climate change?

- How would rain-fed farmers in the region adapt to the impacts of climate change?

Objectives:

- To develop high resolution climate scenario - in geographical and temporal terms
- To understand the impacts of climate change on the regional hydrological regime and rain-fed agriculture in the Mekong River basin.
- To develop and test the framework and method to measure vulnerability of households in the community to climate impacts.
- To understand the coping capacity of rain-fed farmers in the lower Mekong River region to climate impacts and assess adaptation options.

Approach

This study can be divided into 2 parts, which each of which used different approaches.

1. Modeling approach: This area of study focused on changes in climate pattern and its first order impact on hydrological condition and agriculture, particularly the rain-fed system, in the Lower Mekong River Basin. A regional climate modeling technique i.e. the Conformal Cubic Atmospheric Model (CCAM) was used to simulate high resolution future climate scenario for the region. This future climate data was then used to determine climate change impacts on the hydrological regime and on rice productivity in the basin. For the study of the hydrological regime the Variable Infiltration Capacity (VIC) hydrological model was used while for the study of climate impacts on rice productivity, the Decision Support System for Agro Technology Transfers (DSSAT version 4.0) crop modeling software (Hoogenboom et al, 1999) was used to simulate future yield.
2. Field survey approach: This approach was used to assess the vulnerability and adaptation of farmers and included individual household interviews and focus group meeting. The analysis of field interview data was based on quantitative analysis and the multi-criteria method, which used criteria and indicators developed for this case study. The three criteria used in the assessment of farmers' risk of climate impacts are household economic condition, dependency on on-farm production and coping capacity. The potential for adaptation to climate change was also assessed by means of field interviews and a local stakeholders' meeting, to obtain the opinion of farmers in the study sites.

Scientific findings

Future climate change in Southeast Asia: lower Mekong River basin

Climate scenario simulation was conducted for the entire region of Southeast Asia and also the southern part of People's Republic of China for a period of 10 years for each atmospheric CO_2 concentration level. However, the analysis and verification/adjusting process focused only on the Lower Mekong River basin in Lao PDR, Thailand and Vietnam due to the limited availability of observed climate data.

The climate scenario shows that the region tends to get slightly cooler at CO_2 concentration of 540ppm but will be warmer at CO_2 concentration of 720ppm. The change in temperature under this set of climate scenarios is within the range of 1-2 ºC, but the change in the number of annual hot and cool days will be prominent. Hot days, i.e. days with maximum temperature over 33ºC, will increase by 2-3 weeks and cool days, defined as days with minimum temperature under 15ºC, will reduce by 2-3 weeks throughout the region thus pointing to a significantly longer summer in future.

In the case of precipitation, simulation results show a 10-30 percent increase throughout the region under future atmospheric CO_2 concentrations of 540ppm and 720ppm, especially in the eastern and southern part of Lao PDR

Impact of climate change on hydrological regime: Mekong River's tributaries

The CCAM climate model generated a snap shot of climate conditions for one-decade for the lower Mekong River Basin under different CO_2 concentrations. Data on the wettest year and driest year of the decade were used for the hydrological regime simulation, in order to analyze the plausible range of hydrological change under future climate conditions. The simulation result from VIC hydrological model, which focused on major Mekong River tributaries in Lao PDR and Thailand, shows that most of the sub-basins tend to have a higher discharge under the impact of climate change.

Impact of climate change on rain-fed agriculture: rice cultivation

The study of the impact of climate change on rice productivity in Southeast Asia was conducted in 3 study sites selected in Lao PDR, Thailand and in the Mekong River delta in Vietnam using the DSSAT crop model.

Table 5.2: Simulated yield of rice productivity at the 3 study sites under different climate scenarios

Impact of climate change on rice productivity					
Remark: Rice yield shown in kg/ha					
Location	**Climate condition under different atmospheric CO_2 concentration**			**Percent Change compared to the baseline**	
	360 ppm	**540 ppm**	**720 ppm**	**540ppm**	**720ppm**
Lao PDR					
Savannakhet Province					
Songkhone District	2,534.90	2,303.20	2,470.10	-9.14	-2.56
Thailand					
Ubonratchathani Province					
Zone 1	1,154.39	1,235.14	1,330.85	7.00	15.29
Zone 2	1,919.61	2,002.15	2,072.04	4.30	7.94
Zone 3	2,363.70	2,407.62	2,438.92	1.86	3.18
Zone 4	2,542.32	2,575.03	2,591.89	1.29	1.95
Zone 5	3,024.18	3,051.44	3,068.82	0.90	1.48
Viet Nam					
An Giang Province					
Winter-Spring crop	5,592.00	5,741.33	5,357.00	2.67	-4.20
Summer-Autumn crop	4,830.33	4,439.33	2,858.00	-8.09	-40.83
Can Tho Province					
Winter-Spring crop	5,799.67	5,971.00	5,361.33	2.95	-7.56
Summer-Autumn crop	6,778.67	6,783.33	5,627.00	0.07	-16.99
Dong Thap					
Winter-Spring crop	5,578.00	5,877.33	5,153.33	5.37	-7.61
Summer-Autumn crop	4,830.33	4,214.67	2,545.67	-12.75	-47.30
Long An Province					
Winter-Spring crop	5,601.33	5,855.00	5,128.67	4.53	-8.44
Summer-Autumn crop	6,646.67	6,535.00	5,301.67	-1.68	-20.24

The results (see Table 5.2) show that future climate conditions may have a slight negative impact on the rain-fed rice production in the study site in Lao PDR, Savannakhet province with about a 10 percent reduction in yield at a CO_2 concentration of 540 ppm but a reversion to baseline yield at a CO_2 concentration of 720 ppm. In the case of Thailand, simulation results show a positive impact of climate change on rice productivity in the study area in Ubonratchathani province with an increase in yield as high as 10-15 percent in some areas. In Viet Nam, where farmers grow 2 crop cycles in a year, the simulation result shows different climate impacts on rice productivity in each crop cycle. Yield increases slightly for the winter-spring crop at atmospheric CO_2 concentration of 540 ppm, but will drop slightly from baseline year at CO_2 concentration of 720 ppm. On the other hand a significant decline is observed in the summer-autumn crop productivity by approximately 8-12 percent at CO_2 concentration of 540 ppm and by almost 50 percent in some areas at CO_2 concentration of 720 ppm.

Risk and vulnerability of rain-fed farmer in Southeast Asia to climate change

The countries of the lower Mekong River region are largely agriculture-based and have a vast population of rain-fed farmers. The simulation data on rice yield under different climate change scenarios and the analysis of survey data, which focused on change in rice productivity under different climate scenarios and its impact on farmers' livelihoods, showed that vulnerability is site-specific condition, which depends upon the degree of climate impacts and socio-economic conditions as well as physical conditions of each site. The profile of risk to climate change impact would differ from community to community.

In Lao PDR, the livelihoods of farmers are generally at a low risk of climate impacts. At a CO_2 concentration of 540ppm, over 80 percent of surveyed population in Lao PDR is classified under the low risk category, while approximately 10 percent is at moderate risk and only slightly over 5 percent is at a high risk of climate impacts. There is no substantial difference in the situations under normal conditions and extreme climate events. When compared to the baseline condition however, almost one-fifth of surveyed population in Lao PDR is vulnerable to climate change impacts under normal condition while more than half of the population would be vulnerable when climate change impacts are coupled with extreme climate events.

In in Thailand, baseline risk assessment shows that about one-third of survey population is at a low risk of climate impacts, while about 40-50 percent of the surveyed population comprise the moderate risk group. Climate change has a favorable impact on rice cultivation, but extreme climate events can cause a large portion of population to be vulnerable and many households in moderate risk group are now at high risk.

The difference in rice productivity between climate conditions at CO_2 concentration of 720 ppm and CO_2 concentration is 540 ppm is only slight and has little effect on the risk grouping in both case studies in Lao PDR and Thailand.

Adaptation of rain-fed farmers in Southeast Asia to climate change

Rice farmers in the Southeast Asia region are experienced in managing climate risks and employ a variety of measures to reduce their vulnerability that are highly place and time specific and differ according to several social, economic, technological and environmental conditions. Farmers' surveys in Lao PDR, Thailand and Vietnam suggest that selection of measures is shaped by the socio-economic condition of their surrounding community. Surveyed farmers in Lao PDR and Thailand identified numerous practices currently used to lessen vulnerability to present day climate variability and hazards. Some measures are motivated primarily by climate risks while others are motivated by other concerns yet nonetheless reduce climate risks by increasing the resilience of farmers' livelihoods to multiple sources of stress. They include measures that are implemented at the individual farm-level, the community-level, and the national-level.

Farmers in Lao PDR study sites tend to rely mostly on farm level measures for adapting to climate hazards and to a lesser degree on collective actions at the community level. Measures at the national level are very limited. Consequently, the capacity of the individual farm household to adapt is a key limiting factor at present for managing climate risks. Their responses to climate hazards mainly target basic household needs, primarily food security, and common measures include seasonal changes in seed variety, cultivation methods, and timing of farm management tasks based upon seasonal climate forecasts derived from indigenous knowledge. Also common are raising livestock and harvesting natural products for additional food and income.

In Thailand farmers rely on both household and national level measures for reducing climate risks are, while the role of community level measures has declined or been neglected. Household level measures focus on income diversification, primarily from off-farm sources that are not as sensitive to climate variations. The main practice is seasonal migration to work in the cities, which can lead to the permanent migration of some members of the family in order to secure fixed income for the household. Migration to cities is made possible by close links between the rural villages and urban areas where there is demand for labor.

In Vietnam, the reliance is on household level measures aimed mainly at on-farm actions to protect against climate hazards. Community and national level measures play a very limited role. Farm-level solutions include efforts and investments to increase and sustain productivity such as construction and maintenance of small-scale irrigation systems or embankments for flood protection. But investment costs and limited financial capacity of farmers limit wider use of these measures. Therefore some farmers in the study sites have adapted to floods by accepting them as a part of the farmland ecosystem and adjusting the crop calendar accordingly. By allowing their lands to be flooded, they benefit from, the deposited nutrients that enhance soil fertility and pollutants washed away from their farmland. In addition, use of alternate crops and seed varieties are also common adaptation measures used by farmers in the Mekong River delta in Vietnam.

Capacity building outcomes and remaining needs

The activities under this research have contributed towards helping to enhance the capacity of Southeast Asian countries, particularly Lao PDR and Thailand, in the study and assessment of the impacts, vulnerability and adaptation to climate change. These activities served as a hand-on exercise on climate change related issues for participating researchers. This project has also contributed to the formation of a network of more than 20 researchers and research assistants from 3 countries, who were actively involved with this research and are from the following institutes: Chulalongkorn University, Thailand; Chiang Mai University, Thailand; Mahidol University, Thailand; Khon Kaen University, Thailand; Ubonratchathani University, Thailand; Meteorological Department, Ministry of Science, Thailand; Department of Agriculture, Ministry of Agriculture, Thailand; Land Development Department, Ministry of Agriculture, Thailand; National University of Laos, Lao PDR; National Agriculture and Forestry Research Institute, Ministry of Agriculture, Lao PDR; Environmental Research Institute, Science Technology and Environment Agency, Lao PDR; Water Resource Coordinating Committee, Office of the Prime Minister, Lao PDR; and Sub-institute of Hydrometeorology of South Vietnam, Vietnam.

Further research on climate change and its impacts as well as vulnerability and adaptation of various systems and sectors is still necessary and needs to be expanded to the wider range of research networks in the Southeast Asian region. In addition, increasing local research capacity, creating a further network of collaboration among institutions, creating a forum for the exchange of research results, and the development of joint activities that may lead to further policy implementation are important needs. Tools, dataset, methodology, and approaches, developed and used in this study, are made available to academic society and may be used for other climate change research in the future. However, new and improved tools and data, vital for future study of climate change are still very much needed.

National communications, science-policy linkages and stakeholder engagement

The activities under this research have helped to develop research capacity of personnel as well as build networks among institutions in Lao PDR, Thailand and Viet Nam that can assist in or be responsible for the preparation of the Second National Communication to UNFCCC. A greater emphasis is likely to be made on the impacts of climate change on natural systems and human society in the Second National Communication as compared to the first. However expertise and know-how to assess and formulate adaptive strategies in systematic ways are still lacking in the Mekong River countries.

In addition, the outputs of this research, which include tools, data, methodology, analysis summary, etc., will be summarized and disseminated to relevant policy makers as well as other stakeholders in the Southeast Asia region to aid in the further study of climate issues on a wider scale as well as for future policy consideration.

As far as the science-policy linkage is concerned, the principle investigator of this research, Dr.Anond Snidvongs, has been appointed a member of the National Climate Change Committee of Thailand and an associate investigator, Mr.Suppakorn Chinvanno, has also been appointed a member of the working group in developing the national climate change strategy for Thailand.

Policy implications and future directions

This pilot study project has raised awareness among policy makers and public sectors in the region regarding climate change issues. However, for the purpose of formulating policy, policy makers still require more explicit answers regarding climate change impacts, vulnerability and adaptation of various key systems, which need further research. In addition, the study of climate change impact under this regional study is based on a very long timescale, which is too long for the scope of policy planning for any country in the region. Future studies may need to focus on shorter timescales or focus more on climate variability that may change its pattern due to the influence of climate change. Furthermore, greater involvement of policy makers and policy implementing agencies is recommended for future activities. Pilot scale implementation, which may help building resilience to climate impacts and has immediate as well as long-term benefits, such as seasonal climate forecasts, may be further explored.

In addition, climate change impacts in many cases need to be considered at a regional scale since the extent of its impacts may have a large geographic coverage and may have trans-boundary impacts. Furthermore, the efforts to address climate change impacts in one location may cause side effects for other locations or systems or sectors, which could also be a trans-boundary issue. Therefore regional collaboration to establish and share a common understanding of the impacts and adaptation at a larger scale could help develop a collective adaptation strategy to achieve better efficiency and effectiveness in coping with climate stress and also help avoid conflict.

5.3 Assessment of Impacts of and Adaptations to Climate Change in the Coconut and Tea Sectors in Sri Lanka (AS12)

Summary Information

Country: Sri Lanka
Principal Investigator: Dr. Janaka Ratnasiri
Administering Institution: Sri Lanka Association for the Advancement of Science, Colombo, Sri Lanka

Research problem and objectives

Coconut and tea plantations are a major source of revenue in Sri Lanka and provide a livelihood for millions of people. Coconut and tea crops are sensitive to weather, particularly drought conditions, and yields vary directly with rainfall received. With temperature increases and rainfall changes anticipated in the foreseeable future as projected consequences of increasing atmospheric concentrations of greenhouse gas (GHG), it is expected that coconut and tea plantations will be subject to undue stress from lack of water and from lack of solar radiation during extended rainy periods. This project sought to obtain a clear understanding of the dependence of coconut and tea crop yields on climate factors in order to better project future situations.

More specifically, the project objectives were to:

- Project climate change scenarios in the coconut and tea growing areas based on global circulation model results applicable to South Asia.
- Assess the impacts of climate change on the productivity of tea and coconut and on the socio-economic status of the people in the plantation sector.
- Identify adaptation options and assess their feasibility of implementation.

- Build capacity of natural and social scientists engaged in plantation research for undertaking assessment studies incorporating impacts, vulnerability and adaptation.

Approach

Changes in the trends of climate factors such as temperature (e.g., mean, maximum and minimum) and rainfall and their spatial distribution were analyzed in order to separate out the effects of long term climate change from those of short term climate variability. Data on climate variables and crop production statistics as well other factors that contribute to plant growth such as soil properties, radiation levels and relative humidity were also collected. Analysis was carried out separately for different agro-climatic regions.

The study established empirical relationships between crop yield and temperature increases, crop yield and carbon dioxide increases, and crop yield and rainfall changes, based on past performance. Different time durations were analyzed in order to identify the most sensitive time period, which determines future crop yield. Doing so facilitated the development of statistical models for forecasting future crop yields based on past climate factors. For instance, a model was developed for coconut production whereby monthly national production for the coming year was projected successfully based on the quarterly rainfall received during the first three quarters of the current year.

Details of future climate scenarios, which correspond to different emission scenarios, were obtained from relevant reports of the Intergovernmental Panel on Climate Change (IPCC). Software developed by the International Global Change Institute (IGCI) of the University of Waikato, NZ, was selected for use as it could provide temperature (mean, maximum and minimum) and rainfall values corresponding to any location in the country, under any climate scenario. The IGCI model was thus able to generate different climate scenarios for Sri Lanka on the basis of the IPCC emissions scenario, General Circulation Model (GCM), timeframe and site location specified.

The empirical relationships determined by this project as well as others obtained in previous crop yield studies were incorporated into a computer programme that produced crop yield changes as outputs when parameters such as temperature, rainfall, and soil properties were input to correspond to different climate scenarios and timeframes. This software programme was linked directly to the project's climate scenario generator to facilitate direct access to crop output values.

Socio-economic information from the coconut and tea sectors was collected from plantations and other stakeholders for use in developing models to project future socio-economic scenarios. The development of socio-economic models posed a greater challenge, however, than did developing models for natural phenomena (e.g., crop models) because of the uncertainty in human behavior in the long-term.

After identifying climate change impacts on crop yields, measures and strategies for minimizing adverse impacts were also investigated. Cost of implementation was estimated for each potential adaptation measure, and cost-effectiveness was determined. Some trials were initiated as win-win cases to mitigate impacts of prevailing droughts.

Scientific findings

Trend analysis

Trend analysis of the climate data from 1930–1990 revealed that temperature exhibited increasing trends in almost all selected stations and in all three parameters – T_{max}, T_{mean}, and T_{min}. From observations at different stations, T_{max} increased at a rate of +0.0013 to +0.0325 ^{o}C/year, T_{mean} increased at a rate of +0.0013 to +0.0325 ^{o}C/year, and T_{min} increased at a rate of +0.0014 to +0.0312 ^{o}C/year. Rainfall, on the other hand, showed a declining trend at a rate -0.39 to -5.24 mm/year across all major stations but one, which showed a positive trend of +0.99 mm rainfall/year.

Climate data taken from coconut growing areas were analyzed separately for different Agro-Ecological Regions (AERs). There was no significant correlation between the variability of diurnal temperature (Tdif) and rainfall in any AER. There was no significant correlation between Tdif and Tmax in two of the AERs (both located in the dry climate zone and at a low elevation i.e. DL3 and DL5). These results confirm that rainfall and diurnal temperature are two important variables to be used in the development of climate scenarios with respect to annual climate. All regions showed significant increasing trends in both Tmax and Tmin. Only three regions (all at low elevations with one in the wet zone and two in the dry zones i.e. WL4, DL3 and DL5 respectively) exhibited an increment in Tdif. The DL3 region showed the highest rates of increase in Tmax and Tdif. With the exception of one region in the wet zone (WL3), analysis in all other AERs indicated that the Tmax increment is highly responsible for annual warming as opposed to that of Tmin. All AERs except DL3 and DL5 exhibited a decreasing trend in annual rainfall. Analysis of rainfall intensity and the number of rainy days for the AERs in the tea growing areas showed decreasing and increasing trends for both rainfall parameters in different regions.

Climate change projections

The IGCI software was used to obtain temperature change projections for T*max*, T*mean*, and T*min* for 2025, 2050 and 2100 based on outputs of the HadCM3, CGCM, CSIRO and NIES models and the IPCC A1F1, A2, and B1 emission scenarios. The GCM averaged temperature change values obtained for mid-2100 were 2.4, 2.0 and 1.1°C, corresponding to the A1FI, A2 and B1 emission scenario, respectively. The HadCM3 model gave the largest temperature change of +2.5–3.0 °C, while NIES gave the lowest change of +1.1 °C. This range represents the variability within the country.

Rainfall change projections were developed for the same timeframes and emission scenarios with three model outputs. The rainfall change projections for mid-2100 corresponding to the two most extreme emissions scenarios – A1FI and B1 – show increases (maximum of +476 mm/quarter) with respect to the HadCM3 and CSIRO models; the CGCM model indicates decreased rainfall by 2100 (maximum of -190 mm/quarter) with respect to average 1961-90 values.

Statistical model development for coconut

Coconut yield in each AER was correlated with quarterly and seasonal rainfall amounts during the previous year. The results were expressed in the form of a log-linear equation. It was found that the quarterly analysis gave a better representation of yield. The technology dependence of the yield was assumed to be 40 percent, and the balance yield was expressed as an equation with rainfall received in the first three quarters i.e. January-March, April-June and July-September of the previous year. This equation accounted for 94 percent of the inter-annual variability of Annual National Coconut Production (ANCP). The lead-time of this model is up to 15 months. Thus, ANCP for the ensuing year can be predicted by October based on the observed quarterly rainfall of the first three quarters of the current year.

Phenology-based crop model development

The study faced marked difficulties when it attempted to apply the computer-based crop simulation model to coconut production. The model would run with only a fixed set of rainfall values; when rainfall was varied according to new scenarios, the software produced an error message. Due to the lack of user friendliness, the model was later abandoned in its application to coconut.

The model did give satisfactory results, however, when applied to tea production (Table 5.3). Reductions in tea yield expected by 2100 ranged from -19 to -35 percent, -9 to -17 percent and -0.8 to -6 percent, for the low-, mid- and up-country AERs, respectively. The high emissions scenario HadCM3/A1FI produced high-end values and the low emissions scenario CGCM/B1 produced low-end values. For the nearer period of 2050, the yield changes are relatively small and could be either positive or negative, depending on the time frame and scenario adopted. During 2050, the highest tea yield increase of +5.0 percent is expected in the up-country regions (based on the CSIRO/A1FI scenario) while the highest reduction in yields, -7 percent is expected in the low-country regions (under the CGCM/A1FI scenario).

Table 5.3: Projected yield changes under different climate change scenarios

Model/Emission Scenario	Projected Yield Change (percent)								
	Low-Country			Mid-Country			Up-Country		
	2025	2050	2100	2025	2050	2100	2025	2050	2100
HadCM3/A1FI	-0.32	-5.66	-34.67	-0.63	-1.94	-16.78	1.92	3.75	-6.13
HadCM3/A2	0.04	-3.66	-29.33	-0.68	-1.44	-15.02	1.69	3.51	-4.18
HadCM3/B1	-0.24	-2.81	-19.37	-0.77	-1.26	-11.05	1.89	3.25	-2.35
CGCM/A1FI	-2.09	-7.03	-31.14	0.32	0.45	-13.17	0.23	3.02	-3.17
CGCM/A2	-1.73	-5.14	-30.57	0.27	0.50	-11.41	-0.07	2.25	-2.29
CGCM/B1	-2.05	-4.38	-18.80	0.32	0.50	-8.84	-0.07	1.82	-0.83
CISIRO/A1F1	1.85	-3.54	-33.95	0.90	1.31	-15.47	2.39	4.97	-6.13
CISIRO/A2	2.25	-1.49	-30.57	0.81	1.35	-13.04	2.09	4.38	-4.18
CISIRO/B1	1.97	-0.68	-20.41	0.90	1.26	-9.70	2.35	3.98	-0.93

Capacity building and remaining needs

In terms of capacity building, project team members were given the opportunity to attend training workshops arranged by the AIACC Secretariat that introduced participants to various concepts and methodologies available for undertaking climate change studies. While these weeklong workshops did provide knowledge to the scientists about climate change and its impacts, more intensive information sessions would be necessary for those not informed or aware about these topics.

Besides the AIACC workshops, the project team also organized a few additional programmes aimed at building the capacity of scientists to undertake the proposed studies. One such program focused on the use of the IGCI software package. The IGCI team visited Sri Lanka twice, first for an introductory programme and then again to link the initial software to the crop modeling software thus enabling crop yield changes to be read directly from the screen under any climate scenario. However, there were several problems with this software with little user control over its application. It would work satisfactorily with one crop but not with the other. Even when it worked, it was only able to utilizer rainfall data initially fed but not with a new set of rainfall data. The capacity to overcome such situations was not imparted to the users.

A second program focused on building capacity to develop software programmes relating crop yield to relevant input parameters such as climate factors, soil properties, and radiation levels. A senior scientist from the Indian Agriculture Research Institute (IARI) conducted this programme, which included two activities: first, a preliminary training program was held in Colombo; and second, hands-on training with the actual software was provided in New Delhi. Here too, the participants were able to acquire knowledge only on the use of the software rather than its development or troubleshooting. This new software was linked to the IGCI software, which enabled direct reading of crop yield changes corresponding to any emission scenario. One of the executing institutes in Sri Lanka was able to run the software successfully, but the other was not.

A third capacity building programme was arranged in which team members from the Coconut Research Institute (CRI) visited the International Research Institute (IRI) on Climate Prediction at the University of Columbia in New York. One scientist traveled to IRI to learn techniques of short-term climate prediction. And with this knowledge, he was able to forecast, on a monthly basis, the coconut yield one year in the future. A second CRI scientist also visited IRI to learn about economic valuation of product losses due to climate change.

A fourth programme was arranged with the University of Jadavpur for an agricultural economist to develop a socio-economic model to forecast possible changes in the socio-economic future. The model was to be applied to assess changes in crop yield due to changes in non-climate factors alone. Due to time constraints, however, the scientist was able to complete only the initial phase of analyzing past performance.

The two main institutions in Sri Lanka that have a mandate to address climate change matters are the Centre for Climate Change Studies (CCCS), established in the Meteorology Department, and the Climate Change Secretariat (CCS), established within the Ministry of Environment and Natural Resources (MENR). In order to make these institutions more effective and for them play a more tangible role, an important need is their access to adequate resources in both manpower and finances. With adequate capacity, these two organizations could potentially also play a catalytic role in promoting climate change research among scientists in other institutions and universities.

National communication, science-policy linkages, and stakeholder engagement

The Ministry of Environment and Natural Resources (MENR), Sri Lanka's national focal point for the UNFCCC, is in the process of seeking funds to prepare the nation's Second National Communication (SNC). The Principal Investigator for this AIACC project is directly involved in this process. He has also served as a member of the Advisory Committee for a programme undertaken by the MENR as an Enabling Activity Phase II of the Global Environment Facility (GEF) under which a large number of scientists and university faculty were awarded grants for the investigations of impacts, adaptation and vulnerability to be included in the SNC.

Several stakeholder seminars were held to apprise government policy-makers, officials, industry and trade representatives, agriculture scientists, and planters about the project and its preliminary findings. One problem faced by the team was the inability to make firm recommendations with regard to projections on rainfall changes. Unlike in the case of temperature, where the trend is always positive, different GCM outputs indicate different trends for changes in rainfall. Nonetheless, the findings of this project will be useful for future studies in the agriculture sector and for inclusion in the SNC.

Policy implications and future directions

This project's findings with regard to projections for 2100 in the tea sector show a significant decline in tea yield, which, in turn, may result in a decline in national revenue. This will be of important concern to policy-makers. Since Sri Lanka's tea plantations are a mix of both low-country (where the ambient temperature is high) and up-country (where the ambient temperature is low) fields, a decline in productivity in the low country will likely be compensated for by an increase in productivity in the up-country, provided that temperature increases are not too high to exceed optimum temperatures. Up to 2050, this seems to be the case i.e. temperatures will not exceed optimum limits. Beyond that timeframe, however, temperature will likely exceed such limits causing up-country tea yield to decline as well.

In order to counter potential decreases in tea productivity, particularly in the low-country where yield decline is projected to be significant and where the smallholder farmer population is large, the government will need to intervene with financial assistance for those unable to cope. In contrast, corporate sector estates in the up-country will likely not be subject to yield decline except in the latter part of the century. Even then, the estates will likely have the adaptive capacity to take preventive measures.

Another possible adaptation option is the conversion of non-productive tea land to land used for growing other crops (e.g., energy plantations comprised of short coppice plants to feed small power plants in rural areas) or for growing timber species, which are expected to increase in value because of high demand in the construction and furniture industry. Substitution of biomass in electricity generation and in the construction industry (as a substitute for steel) will fall in line with sustainable development and help in the mitigation of GHG emissions.

With the release of its Fourth Assessment Report, the IPCC has provided revised projections of climate change with reduced uncertainties, particularly with respect to the disagreement between GCMs. There is a need to update national studies on impacts based on these revised projections. Scientists will be in a better position to alert policy-makers and press for firm action once uncertainties in the projections are reduced.

Another activity that must be addressed is widening the scope of climate change studies to cover the entire agriculture sector in Sri Lanka, including other important crops such as rice, rubber and sugar cane. There are crop simulation models available for annual crops, and their application will require fewer resources than for perennial crop simulation. The capacity of both the CCCS and CCS will need to be strengthened for this purpose.

5.4 An Integrated Assessment of Climate Change Impacts, Adaptations, and Vulnerability in Watershed Areas and Communities in Southeast (AS21)

Summary Information

Country: Philippines and Indonesia
Principal Investigator: Dr. Rodel D. Lasco
Administering Institution: Environmental Forestry Programme (ENFOR), University of the Philippines, Laguna, Philippines and Bogor Agricultural University, Indonesia

Research problem and objectives

The continued rise in greenhouse gasses (GHG) is likely to lead to significant changes in mean climate and its variability in the Asian Region (IPCC, 2001). All Global Circulation Models (GCMs) predict an enhanced hydrological cycle and an increase in area-averaged annual mean rainfall in Asia. This is expected to exacerbate pressure on the region's natural resources that are already under severe stress from rising population. Key concerns in Southeast Asia include the impacts of climate change on ecosystem vulnerability (e.g. biodiversity loss) and water resources. Scarce information is available on these concerns and specifically lacking are integrated assessments of impacts, adaptation and vulnerability (IPCC, 2001).

In the Philippines, watershed areas are critical to the country's economic development and are likely to be adversely affected by climate change. More than 70 percent of the country's total land area lies within watersheds including areas covered by natural forests that provide a host of environmental services. An estimated 1.5 million hectares of agricultural land presently derives irrigation water from watersheds. Moreover, around 20 to 24 million people – close to one-third of the country's total population – inhabit the uplands of many watersheds, a majority of which depend on its resources for survival. However scientists working on climate change in Southeast Asia have limited experience in impacts and vulnerability assessment.

Only one national level study on vulnerability assessment and adaptation, The Philippines Initial National Communication on Climate Change (1999), has been completed thus far and none are on-going or planned A preliminary vulnerability assessment for a watershed area in the country suggests that changes in precipitation could result in a –12 percent to 32 percent change in runoff depending on the GCM used (Jose *et al*, 1996). The 1999 National Communication also highlighted the need for the vulnerability assessment of major reservoirs and rivers in the country as well as impacts on major water users. Information on the impact of climate change on local communities inhabiting watershed areas and on natural forest ecosystems is completely lacking.

In Indonesia, a study on regional water balance using 1995 data, found that most watersheds in Java are already at critical stage and thus vulnerable to the impacts of climate change. The ratio between water demand and supply in some watersheds is already close to one and more than one in a few (e.g. in Brantas watershed it is 1.12). Outside Java the ratio is mostly less than 0.76. In the last decade, during El Niño years, most of the rice growing area in Java and some in South Sumatra (e.g. Lampung) suffered from severe drought due to a significant decrease in water supply from the reservoirs (Las *et al*, 1999). On the other hand, during La-Nina years flooding is common in some regions (Jazis *et al*, 1999). As in the Philippines, studies on the impact of climate change, in particular on water resources and forest ecosystems are lacking.

The impact of doubling CO_2 on Indonesia's rainfall, forest productivity and crop production has also been evaluated (Boer *et al*, 2000; Amien *et al*, 1996). Under CO_2 doubling, annual rainfall in southern Indonesia (Java and eastern Indonesia and part of Sumatra) might increase while in the northern Indonesia (Kalimantan, Sulawesi) it would decrease, and this is consistent with historical data. Similarly, forest and crop productivity may also change depending on location.

Scientists working on climate change in the Philippines and Indonesia have limited experience in impacts, adaptation and vulnerability assessment. Lack of research support from internal sources has stifled development of research capacity. Aside from resource constraints, strategic partnerships with scientists from developed countries are also required. The lack of research is reflected in the absence of articles from the Southeast Asian region in peer-reviewed literature. The result is an under-representation of cases from the region in the IPCC assessment reports.

This study was designed to address this lack of scientific research on climate change impacts, adaptation and vulnerability of watershed resources and local communities in the Philippines, Indonesia and Indo-China.

The main objectives of the study were to:

- Assess the impacts of climate change on water resources, forest ecosystems, and social systems of the watersheds;
- Conduct integrated vulnerability assessment of natural and social systems in the watershed areas;
- Develop adaptation strategies for natural water resources, forests ecosystems and social systems;
- Promote stakeholder participation in the research process;
- Contribute to peer reviewed literature; and
- Help build capacity of local scientists to conduct integrated assessment studies.

In the Philippines, the study was conducted in Pantabangan-Carranglan Watershed (PCW) in Nueva Ecijia Province. In Indonesia, the study was conducted in Citarum Watershed in West Java.

Approach

The general framework of the study is shown in Figure 5.1. The study used climate change scenarios generated by GCMs as well as current climate coping mechanisms as starting points. An integrated assessment of impacts, adaptation and vulnerability of natural and social systems was conducted.

The study also characterized recent and future trends in rainfall and temperature along with land use and land cover and the associated patterns of streamflow. Description of recent trends was primarily made by using available records of observed climatology and hydrology. Characterization of future trends in climate was achieved by downscaling regional GCM results. The CLUE-S model was used to project the likely land use scenarios while SEA-BASIN model was used to predict the future changes in streamflow resulting from changes in climate and land use and land cover.

To assess climate change impacts on Philippine forests ecosystems, the study used GIS and the Holdridge Life Zones to simulate vegetation changes. Synthetic scenarios of precipitation and air temperature were used within the limits of GCM projections for the country.

Furthermore, other tools such as desk study (simulation modeling), survey and stakeholder interviews (local government, electricity companies, water drinking state company and local community) were also used.

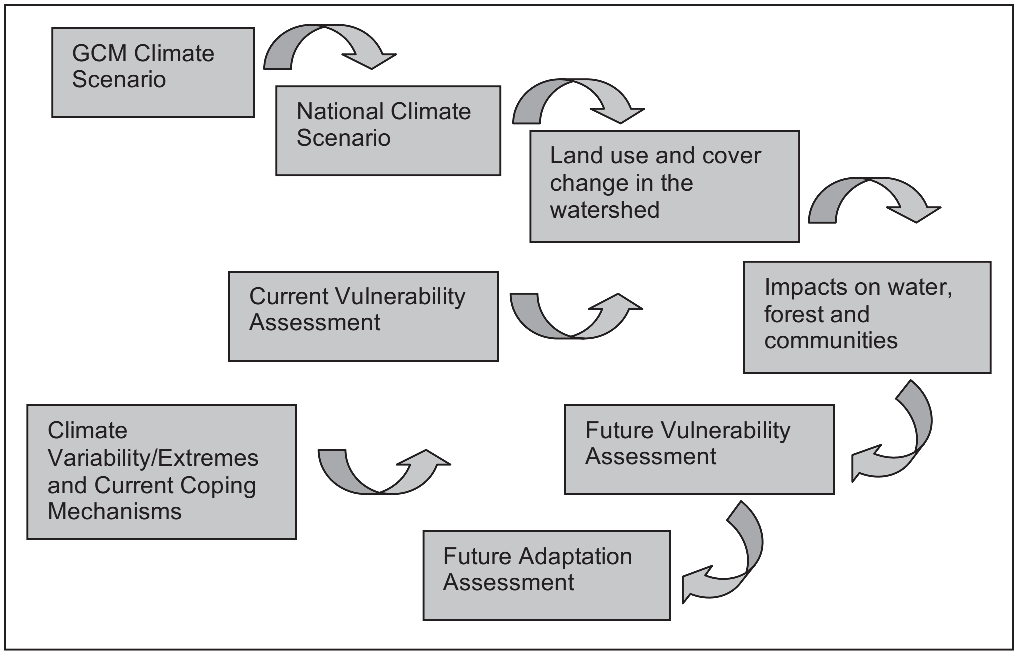


Figure 5.1: General Framework of the study.

Scientific findings

The study revealed that by 2080 rainfall in the Pantabangan-Carranglan Watershed (PCW) is projected to increase by as much as 12.7 percent and temperature by more than 5 percent of the average observed daily values between 1960 and 1990. This change in climate could translate into about 17 percent increase in the wet season streamflow and a decrease of around 35 percent in dry season streamflow of the PCW. The increase in streamflow could lead to a higher likelihood of floods in the service areas of Upper Pampanga River Integrated Irrigation System (UPRIIS) than it is at the present. Likewise, the projected decrease in streamflow of the PCW during the dry season will likely increase the incidence of water shortage, which could be aggravated by the increasing water demand due to increasing temperature. The projected changes in climate and the associated changes in streamflow patterns of the PCW will likely have more serious impacts on lowland farmers in the absence of a deliberate program to reduce the vulnerability of lowland farmers to floods and water shortages.

The assessment of vulnerability of the watershed by land use with the aid of Geographical Information System (GIS) revealed that more than 65 percent of the entire PCW is moderately vulnerable to climate extremes and change while more than 25 percent is highly vulnerable. Most of the highly vulnerable areas are forests, grasslands and brushlands by virtue mainly of their location on steep and highly elevated locations and proximity to roads. Moderately vulnerable areas are largely grasslands, brushlands and forests.

Vulnerable places identified by the local communities in the PCW during Focus Group Discussions (FGD) include low-lying flood-prone settlement areas, agricultural areas prone to floods and droughts, dying streams/rivers, farmlands at the tail-end of irrigation canal, highly erosive areas (in steep slopes) along riverbanks, unstable areas with steep slopes that support infrastructure, and grasslands and forested areas/plantations near roads and settlements susceptible to fire.

Using the Holdridge life system, simulation of future climate change showed that dry forests in the Philippines (more than 1 M ha) are the most vulnerable. They will be eliminated even with a 50 percent increase in rainfall. If rainfall doubles, even the moist forests (3.5 M ha) will be totally replaced. On the positive side, the wet and rain forest life zones will significantly expand as dry and moist forests become wetter. Thus, overall, it is expected that the total forested area in the Philippines will not decline.

In Indonesia, the study showed that Citarum watershed is very vulnerable to climate change and there could be an increased risk of drought and flood in the future if deforestation is not stopped and there are no significant efforts to increase forest cover. Based on simulation studies, it was found that a minimum forest cover of about 25 percent is required to minimize the impact of climate change in the future.

Active participation of the local community in the Citarum Watershed for protecting and increasing forest cover is very important to ensure the success of reforestation activities. However, the study suggests that upstream communities may continue deforestation in the absence of alternative livelihoods. Developing a reward system for encouraging upstream communities to increase forest cover and avoid deforestation has been found to be one of the effective ways to reduce the rate of deforestation. Communities can avoid deforestation by increasing land use intensity or finding suitable alternative income generating activities such as raising livestock and trading. The downstream community has expressed willingness to support activities or programs for maintaining and increasing forest cover in the upstream watershed by paying a higher price for drinking water. The electricity company (Indonesian Power) is also willing to support community reforestation activities through a community development program. With these efforts, it is expected that a minimum forest cover of 25 percent could be achieved to ensure a continuous supply of water during dry season and extreme drought years.

Capacity building outcomes and remaining needs

The limited capacity of developing country scientists in the Asia-Pacific region to conduct vulnerability assessment and adaptation planning is well recognized (Zakri *et al*, 2000). Thus, a key feature of this project was the enhancement of capacity of local researchers to conduct climate change impact and vulnerability assessment. By working with developed country scientists from partner organizations, (ICRAF and GCTE) there was a transfer of skills and know-how in modeling and assessment tools. Aside from the researchers, other stakeholders within the Philippines and Indonesia benefited as they participated in the research process. Training courses and technical assistance for scientists from Indo-China (Laos, Vietnam and Cambodia) were also implemented by the project as part of its capacity building efforts in the region. Furthermore, several graduate and undergraduates students had participated actively during the implementation of the project.

Key members of the research team were involved in various capacities in the preparation of Philippines' first national communication and maintain regular contact with the Philippine Interagency Committee on Climate Change secretariat. The research team initially presented the project objectives through workshops with the Department of Environment and Natural Resources (DENR), Local Government Units (LGUs), National Irrigation Administration (NIA), National Power Corporation (NPC), Non-government Organizations (NGOs), and People's Organizations (POs) to generate awareness about the project and regular updates on project findings were provided to stakeholders. Trainings in climate change impact assessment methods were conducted to capacitate local scientists and stakeholders. Research teams members also regularly presented project results at several conferences and workshops. In Indonesia, a number of public awareness building activities have been conducted via seminars and dialogues with local government, local NGOs and local communities. Trainings on the use of simulation modeling approach to assess climate change impacts were conducted at the regional and national levels for scientists from least developed countries and national research agencies and universities. Further requirements include training in socio-economic scenario development in climate change studies and institutional studies (regulations and local institutions system) for the development of a reward system for communities providing environmental services.

National communications, science-policy linkages and stakeholder engagement

This project is well positioned to contribute to the Philippines second National Communication. One of the team members, Ms. Joycelline Goco heads the preparation of the second National Communication as the chair of the Philippine Inter-agency Committee on Climate Change. Project staff also had the opportunity to participate in the initial consultations for the second National Communication. Many findings from the AS21 project, including climate projections and local adaptation strategies, are expected to provide direct inputs by addressing ropics related to disaster preparedness in the national communication. Furthermore, the project team, in cooperation with the Philippines Atmospheric, Geophysical, and Astronomical Services Administration (PAGASA) also plans to prepare climate change projections for the entire Philippines and the results are to be included in the national communication.

In Indonesia, the results of this study have been communicated to the climate change focal point. The government is now in the process of preparing the second national communication and the principal investigator of this project has been invited by the Ministry of Environment to assist with this task. The focus of the second national communication will be on adaptation, which was not addressed in the first national communication due to a lack of understanding and a lack of authoritative studies on the topic.

Policy implications and future directions

At present, climate change is hardly considered in the planning process of the government. There is therefore a need for bottom-up assessment and planning to address vulnerability and enhance adaptive capacity at the local and national levels. Participatory action research engaging the different stakeholders should be pursued to minimize the vulnerability of the poor and enhance adaptive capacity at the local level. Policies and development programs should aim to empower local communities to broaden their range of choice of appropriate strategies rather than making them dependent on external support. However, this should not preclude questioning the large-scale cause of vulnerability such as poverty, inequity and institutional and economic barriers to development including the issue of power and conflicts (Brooks, 2003).

The specific policy recommendations that arise from our study are the following:

- Integrate climate-related risks in watershed planning and management
- Integrate climate-related risks in community-based programs

In order to streamline the action plan of adaptation to climate change impacts into the national development program, further awareness building is necessary either through science-policy forums or creation of a national working group on climate. Due to the devastating impact of ENSO phenomena on many sectors, the Indonesia government has created a number of national working groups to address these issues and advise policy makers on actions required to anticipating such events. It is recommended that future research should focus on strategies for institutionalizing climate information and for encouraging and engaging local communities towards protecting and improving the environmental quality in sustainable ways.

5.5 Vulnerability and Adaptation to Climate Variability and Change in Western China (AS25)

Summary Information

Country: People's Republic of China
Principal Investigator: Dr. Yongyuan Yin
Administering Institution: International Earth System Sciences Institute (ESSI), Nanjing University, People's Republic of China

Research problem and objectives

The purpose of the project is to develop an integrated approach (IA) for identifying regional vulnerabilities to climate variations and change, and for prioritizing adaptation options to deal with climate change vulnerability.

The study region is the Heihe River Basin in Northwestern China and the target sectors include food supply, water resources, land use conflicts, and ecosystem deterioration. Heihe River Basin predominantly includes the arid and semi-arid areas in the North and is dominated by mountains in the South. With barriers such as extremely fragile ecological conditions, fewer financial resources, poor infrastructure, lower levels of education, and lesser access to technology and markets, the region has been suffering from the effects of climate variations and may experience severe impacts of climate change on food production, water resources, and ecosystem health. Moreover, the region's adaptive capacity is lower than that of the coastal region of China. People in this region face substantial and multiple stresses, including rapidly growing demands for food and water, large populations at risk of poverty and infectious diseases, degradation of land and water quality, and other issues that may be amplified by climate change.

Approach

The research project adopts an integrated assessment (IA) approach (Figure 5.2), which provides a framework to integrate climate change scenarios, socio-economic scenarios, current climate vulnerability identification, climate change impact assessment, sustainability indicator specification, adaptation option evaluation, and multi-stakeholder participation. The IA provides an effective means for the synthetic assessment of climate vulnerabilities and evaluation of the general performance of a set of adaptation options through multi-criteria and multi-stakeholder decision making processes. Different computer modeling and non computer-based methods were adopted to form the integrated approach. These include survey, workshops, community engagement, multi-stakeholder consultation, general circulation models (GCMs) and regional climate model (RCM), ecological simulation modeling, GIS, remote sensing and multi-criteria decision making (MCDM).

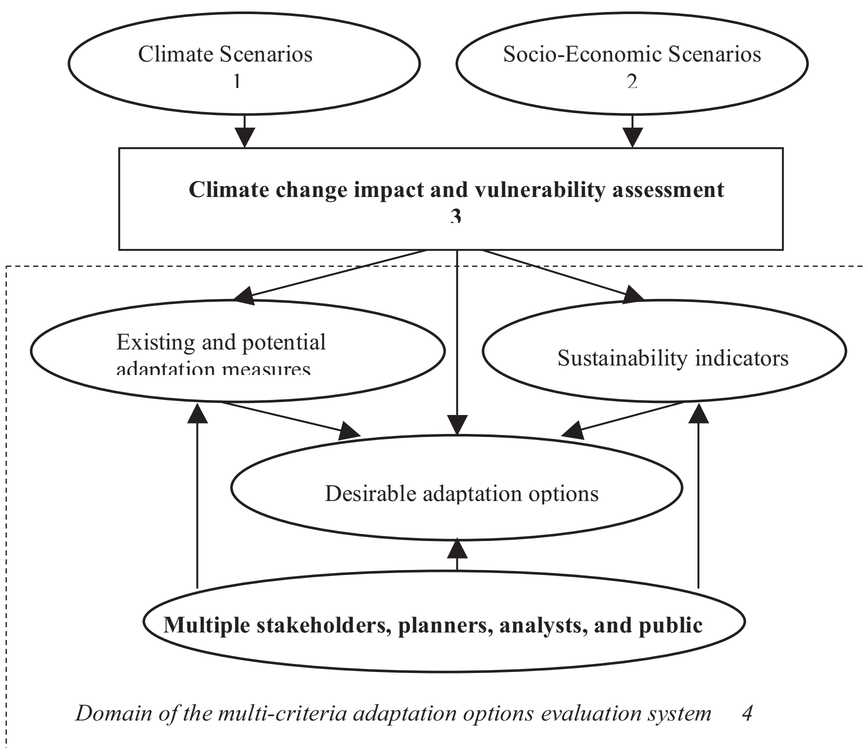


Figure: 5.2: Flow-chart showing the research structure of the project

Scientific findings

Since its official beginning in August 2003, the research project has examined, the extent to which three key sectors in the Heihe River Basin are vulnerable to climate variations and change; the potential environmental and socio-economic impacts of climate variations and change; and adaptation options desirable to deal with climate vulnerabilities. In particular, the study has accomplished the following:

- An integrated assessment (IA) approach has been successfully developed to identify societal vulnerabilities to climate change scenarios. The approach integrates climate and socio-economic scenario setting, climate change impact assessment, vulnerability identification, adaptation option evaluation, multi-criteria decision-making, and multi-stakeholder participation.
- The IA was applied in the study region to assess current and future climate vulnerability and risks, and to prioritize adaptation options. The IA approach was also applied in the Heihe River Basin to evaluate a number of climate change adaptation options for the arid and semi-arid regions and communities of the study area.
- A series of workshops and policy surveys were conducted with participation by a broad range of public and private stakeholders, to identify sustainability indicator priorities, as well as desirable adaptation policies.
- Overall the study has improved understanding of the interactions between regional sustainability and climate change impacts. The project findings have yielded desirable and practical adaptation options and/or plans to effectively address climate change impacts and ensure sustainable development.
- Thirteen graduate students and five local scientists received training in designing and applying IA methods in a real world context.

Major findings of the project are summarized below

Climate change trends and scenarios

Recent climate change trend in northwest (NW) China for the past 50 years was investigated by analyzing the temperature and rainfall from 1951 to 2004. The main results are:

- Daily mean temperature increased significantly, with its linear trend in most areas ranging from 0.2ºC/10year (yr) to 0.4ºC/10year, especially in Xinjiang, Qinghai and Inner Mongolia. Daily maximum temperature and daily minimum temperature also showed similar trends over the last 50 years with the increase in minimum temperature more significant, than that of maximum temperature. Extreme warm events also increased considerably during this period.
- Rainfall in areas west of 102.5E in NW China increased significantly, with the maximum linear trends reaching 15 percent/10yr, while areas east of 102.5E experienced a decrease. Rainfall increased most in the summer and extreme rainfall events increased considerably in areas west of 102.5E.
- From 1961 to 2003, the temperature in the Heihe River Basin increased significantly. The linear trends were greater than the average for both China and NW China. Rainfall in this study region showed an increasing trend weaker than that of NW China.

Based on eight coupled global atmospheric and oceanic circulation models (AOGCMs), the climate change projection over West China for the 21st century was calculated by the NCC/IAP T63 (National Climate Center/Institute of Atmospheric Physics) model. The emission scenarios took account of the anthropogenic greenhouse gases (GHG) emission and GHG plus sulfate aerosol (GS) increases, as well as IPCC SRES A2 (high emission) and B2 (medium emission). The anomalies of both temperature and precipitation were relative to the 30-year mean of 1961-1990. Major projections are:

- A likely obvious warming over West China in the 21st century, especially in NW China i.e. an increase in temperature anomalies for the SRES scenarios by 1.0-2.5ºC by about 2050 is possible. The warming over West China might be higher than the mean warming for the whole country. The annual mean temperature change over NW China around 2050 relative to 1961-1990 is expected to be 3.5-6.5ºC for A2 and 2.5-4.5ºC for B2.
- Precipitation over most parts of West China, especially in NW China is likely to increase by about 5-30 percent for A2 and 5-25 percent for B2 by about 2050 relative to 1961~1990.

In addition, a nested regional climate model (RCM) was used to investigate climate change over western China for the future 30 years with SRES A2 emission scenario. The change trends and features of precipitation (P) and temperature (T) are:

- A slight decrease in precipitation over northwest China in 2020 and then an increase in 2030 over NW China and parts of southwest (SW) China with weaker annual change.
- An increase in air surface temperature for the entire western region (especially in summer), with annual mean increase value of 0.4ºC, which is lower than eastern China.
- An increase in Tmax and Tmin with larger Tmin increases than Tmax due to which, a future decrease is expected in the daily range of Ts.

Climate vulnerability assessment

By using vulnerability indicators, the climate vulnerability of the study region under current climate conditions was investigated. Results indicate the relative vulnerability levels of land and water systems in different areas exposed to current climate stimuli. Key climate vulnerabilities in the region include:

- Water withdrawal ratios (ratio of average annual water withdrawal to water availability) in the Heihe River Basin are extremely high (83-125 percent) under current climate conditions, far exceeding critical threshold levels set by the World Meteorological Organization and Chinese government.
- The Palmer drought severity index (PDSI) trends in the growing season for the lower and middle reaches of the Heihe River Basin indicate that study areas have become drier in the past decade. This trend is expected to continue under a changing climate.
- Water use conflict has shown an increasing trend over the past decade in the study basin, which suggests an increasing severity of water shortage in the growing season because of decreased water supply and increasing population and per capita water use.
- Water shortage vulnerability in Heihe River Basin ranged from most vulnerable to the least vulnerable for nine counties in the region. Climate change is also expected to have varied impacts on water system vulnerability across these counties.
- Vulnerability maps generated by mapping indicators with geographic information system (GIS) show the relative vulnerability levels of water and land resources in different areas exposed to current climate stimuli. A map of composite indicators representing the vulnerability of both agricultural and domestic water users to climate stresses in the form of long hot and dry spells was also generated to identify areas of high vulnerability in the region as a whole.
- Climate change impacts on the agricultural sector include more frequent and severe droughts and land degradation and arable land loss problems, which would add to existing issues of limited water supplies that restrict agricultural production and threaten future food security. Agricultural production vulnerability to climate change also varied across the nine counties.
- Results of the Normalized Difference Vegetation Index (NDVI) and land degradation map indicate that vegetation in the northern part of the basin is the most severely affected, while conditions are better in the south.
- Ecosystem vulnerability to climate change in the Heihe River Basin is also high. The degree of vulnerability is highest in the lower reach of the basin, which is largely unmanaged grassland under extreme arid conditions, and improves gradually over the middle and upper reaches.
- Compared to the year of 2000, the pressure on ecosystems in the Heihe River Basin will increase significantly in 40 years. The rate of the Human Appropriation of Net Primary Productivity (HANPP) is expected to surpass 50 percent (dangerous level) even under the best social economy scenario and in some areas, the HANPP rate will likely overshoot the system collapse limit.

Adaptation Options Evaluation

A method designed by Yohe and Tol (2002) was used to evaluate alternative adaptation options for water resource systems by using adaptive capacity determinants. The results indicate that the feasibility of adopting technical and engineering adaptation practices is relatively low due to a lack of financial resources. On the contrary, water-saving practices such as cropping and cultivation structure adjustments are more feasible because of relatively small capital requirements.

The rank ordering of all water adaptation options evaluated using the Yohe and Tol (2002) method is as follows (from the most desirable and effective to less effective): adjusting crop structure; adopting more effective water-saving irrigation plans; preventing water leakage from irrigation channels; reducing land surface evaporation using plastic film and crop straw coverage; conserving soil moisture by deep plow method; adopting drought-tolerant crop varieties; expanding more advanced irrigation techniques including sprinkle, drip irrigation, and low-pressure irrigation pipe lines; building new reservoirs in up reach area to regulate flow distribution; and increasing groundwater exploitation.

An analytic hierarchy process (AHP) method, a multi-criteria decision making (MCDM) technique, was also used as an evaluation tool to identify the priorities of evaluation criteria and to rank desirability of alternative adaptation measures. Reforming the economic structure was ranked the most desirable adaptation option for the Heihe River Basin followed by establishing farm water users' society. Relatively new options such as improved water allocation policies, establishing water permits and trade, and increasing awareness and education options scored moderately. Options like applying water saving equipment and technologies and implementing water price system options were considered expensive by participants and were ranked low. Constructing water works was considered to be the most economically inefficient option and ranked the lowest.

Capacity building outcomes and remaining needs

Building scientific capacity to conduct climate vulnerability and adaptation assessment was a primary concern of the project. The project provided training to enable local decision makers and multi-stakeholders to understand the linkages between climate change and sustainability. The regional climate change impact and adaptation study was undertaken by local scientists in partnership with U.S. and Canadian experts. Specifically, the project contributed to enhancing scientific capacity in the following ways:

- Improved understanding of the interactions between regional sustainability and climate change.
- Trained young scientists and graduate students to design and apply integrated assessment methods in a real world context (About 20 young scientists and PhD students participated in the project). Young scientists were trained in conducting research activities, organizing and attending workshops, applying various models, and conducting householder surveys for adaptation options evaluation. Thirteen PhD and Master students contributed to the project and three Ph.D. theses were derived from research activities of the project. A training course was arranged in CAREERI, Lanzhou, October 2004 to improve graduates' skill in conducting vulnerability and adaptation assessment.
- Involved multi-stakeholders and local experts in many project activities (A training workshop was held in Lanzhou, in August 2002).
- Interviewed and surveyed farmers either individually or in a small group workshop-type setting in Heihe region.
- Partnered with the Canada-China Cooperation in Climate Change (C5) Project funded by the Canadian International Development Agency (CIDA). China's Office of the National Climate Change Coordination Committee (NCCCC) of the National Development and Reform Commission (NDRC), and the Chinese Academy of Agricultural Sciences (CAAS) held an International Adaptation Conference entitled, *Climate Change: Building the Adaptive Capacity: An International Conference on Adaptation Science, Management and Policy Options* in May 2004 in Lijiang, China.
- Helped CMA in organizing an international symposium on arid climate change and sustainable development (ISACS), held in Lanzhou, May 23-24, 2005. A special session for this project was included in the ISACS Conference.

National Communications, science-policy linkages and stakeholder engagement

The activities of this project included workshops, survey, and community engagement methods, which were employed to involve multiple stakeholders, policymakers, and experts in the study process. During the course of the project, the research team built committed partnerships with multi-stakeholders at national, provincial and local level. An essential part of the stakeholder engagement strategy of this project was the establishment and participation of the Chinese Steering Committee and Technical Committee consisting of key government agencies and experts responsible for China's international cooperation on climate change issues and national communications.

The Steering Committee (SC) included the following government agencies: National Climate Change Coordinating Office of National Development and Reform Commission (NCCCC/NDRC), Chinese Meteorology Administration (CMA), China GEF Office, State Environmental Protection Administration (SEPA) and the two investigators of this project. The NCCCC is the Chinese agency responsible for leading China's National Communication Report. The Expert Committee (EC) consisted of experts who had experience from previous GEF climate change projects and contributed with their skill and data to this study.

The main interaction between this project and China's National Communications was in involving Chinese government officials and experts responsible for preparing China's National Communication in this project. Since the executing agencies and key experts responsible for China's National Communication are also partners in the project (i.e. project Steering and Expert Committee leaders and members), the study results can make a useful contribution to the National Communication. In addition, the principle investigator, Dr. Yin was involved in the Canada-China Cooperation on Climate Change (C5) project, which consisted of a "National Communication" component.

As a part of this project three project and committee workshops were held. All key members of the Steering and Expert Committees participated in the workshops and provided their suggestions and advice. Ms. Sun Cuihua and Prof. Lin Erda, two key persons responsible for preparing the Chinese National Communication Report, were invited to attend the AIACC Asia-Pacific Regional Workshop in Manila, November 2004 to present China's climate change policies and National Communication report.

Policy implications and future directions

Working in partnership with local, provincial and national governments and other key stakeholders (water use professionals, farmers, and other organizations), the study identified alternative effective adaptation measures that could become practical solutions to address water resource vulnerabilities which would likely become more severe in the study region due to the impacts of climate change. A properly developed and implemented adaptation action plan could have positive benefits for the well-being and productivity of all people living in the region and could help reduce water use conflicts.

Since water is the key determinant which influences all the economic activities and livelihoods of the region, a reduction in water resource vulnerability will help mitigate the impacts of climate change on the agricultural sector and protect the livelihood of farmers. Water system sustainability can also improve ecosystem health and reduce sandstorms. The study serves as an information source for decision-makers to improve the adaptive capacity of resource systems to cope with climate risks in Heihe River Basin. The project also:

- Conducted policy surveys of alternative adaptation options or measures that could reduce water resource risks from climate change in the study region;
- Prioritized alternative adaptation measures and identified desirable adaptation options that could help the water infrastructure in the study region to cope with climate stresses;
- Improved local capacity for climate risk assessment and adaptation evaluation; and
- The research team has also published journal papers and a textbook that introduces a wide range of research approaches, methods, and tools for assessing climate-change impacts, vulnerabilities, and adaptation.

As a reasonable follow up, the project team is exploring options to develop a pilot adaptation action plan that could become a useful model for communities across the study region to reduce climate risks and rural poverty, and thus to improve livelihood in poor regions.

5.6 References

Bayarbaatar, L., G. Tvuaansuren, and D. Tserendorj. 2005. 'Climate Change and Livestock'. In P. Batimaa and B. Bayasgalan, eds., *Climate Change Impacts on Extremes – Vulnerability and Adaptation Assessment for Grassland Ecosystem and Livestock Sector in Mongolia: Impacts of Climate Change.* ADMON. Ulaanbaatar (in Mongolian).

Boer, R., Notodiputro, K.A. and Las, I. 2000. Prediction of daily rainfall characteristics from monthly climate indices. In Proceedings 'The Second International Conference on Science and Technology for the Assessment of Global Climate Change and Its Impacts on Indonesian Maritime Continent', 29 November-01 December 1999.

Brooks, N. 2003. Vulnerability, Risk and Adaptation: A Conceptual Framework. Tyndall Centre for Climate Change Research Working Paper 38.

Hoogenboom, G., P.W. Wilkens, and G.Y. Tsuji (eds.). 1999. DSSAT version 3 v4. University of Hawaii, Honolulu, Hawaii.

Intergovernmental Panel on Climate Change (IPCC). 2001. Summary for Policy Makers. The Regional Impacts of Climate Change. An Assessment of Vulnerability. A special Report of the IPCC Working Group II. Cambridge University Press.

Jose, A.M., L.M. Sosa and N.A. Cruz. 1996. Vulnerability assessment of Angat Water Reservoir to climate change. Water, Air and Soil Pollution 92: 191-201.

Mongolian Statistical Yearbook, 2001. National Statistical Office, Ulaanbaatar, Mongolia.

Mongolian Statistical Yearbook, 2003. National Statistical Office, Ulaanbaatar, Mongolia.

The Philippines' Initial National Communication on Climate Change. 1999. Republic of the Philippines.

Yohe, G. and Tol, R.S.J. 2002. "Indicators for social and economic coping capacity – moving toward a working definition of adaptive capacity" Global Environmental Change (12): 25-40.

6 Climate change assessments in Latin America

Five studies on the impacts of and adaptation to climate change were undertaken in Latin America under the AIACC project. One of these focused on water resources and agriculture in the Central American countries. Two projects were based in the basin of the La Plata River in Argentina and Uruguay, one addressing impacts on coastal zones and human settlements and the other dealing with biodiversity impacts. A fourth project dealt with rural economy and food production in three countries, Argentina, Brazil and Uruguay, primarily focusing on climate change impacts on mixed crop / livestock production systems. The fifth study addressed agriculture and water resource sectors in Mexico and Argentina. Summary information on individual case studies is provided below.

* Details about the scientific literature referenced in the project summaries below are available in the final project reports accessible at: http://www.aiaccproject.org/Final Reports/final_reports.html

6.1 Impacts and Adaptation to Climate Change and Extreme Events in Central America (LA06)

Summary Information

Country: Guatemala, Belize, El Salvador, Honduras, Nicaragua, Costa Rica and Panama
Principal Investigator: Walter Fernandez
Administering Institution: Comité Regional Recursos Hidraúlicos (CRRH) del Sistema de la Integración Centroamericana (SICA), San José, Costa Rica.

Research problem and objectives

Extreme climate events represent an important factor that affects development and welfare in Central America. Climate change could further exacerbate this situation failing the timely incorporation of appropriate adaptation options into development plans. One of the main hurdles in this process is the lack of participation from all actors of Central American society in climate change issues, a problem perceived by many as distant, diffuse and uncertain. The objective of this project is therefore to increase social awareness about climate change in general and particularly target large business that generate employment, export goods, provide services and generate wealth for Central America. The two important sectors of Central American economy are water resources and agriculture, which are also the most vulnerable to the extreme climate events and could be greatly impacted by climate change.

Approach

Climate change scenarios were developed for the study region with MAGICC and SCENGEN using as inputs, greenhouse gas (GHG) emissions (Alvarado et al, 2005). Scenarios were built for the following time horizons: short term 2010, 2020, 2030; mid time 2040, 2050; long term 2075, 2100. Model results were referenced to actual climate and validated using actual data as well as information from Magana et al 1999, and Magana et al, 2003. Identification of extreme climate events in Central America were based on the data base developed by Campos and Ortiz (2005) from daily news reports of extremes from 1950 to 2005, which were cross referenced with meteorological data and reports from emergency management institutions for Central America (Database "Desinventar", La red, 2004). Flood and droughts are the main manifestations of extreme climate in Central America, causing close to 85 percent of all disasters in the region. Studies undertaken under this AIACC project have attempted to determine impacts of climate change scenarios on such extreme events and the economic impacts of such extreme events in this region.

Parallel to the climate change studies, a study to examine water capital, water users and their projected demand was developed in collaboration with the Freshwater Ecosystem Program for Mesoamerica of the World Union for Nature (IUCN) and the Global Water Partnership for Central America (GWP-CATAC). A qualitative estimation of the potential impacts of climate change in the water sector was done based on the information from climate change scenarios and water availability for Central America.

Two case studies were also developed for the agriculture sector, one in a region of Nicaragua highly affected by drought, particularly during the El Nino period, and the other along the Caribbean coast of Costa Rica and Panama characterized as a very productive zone for banana and frequently affected by flooding. Understanding actual adaptation options through these case examples would make it possible to increase resilience in both sectors important for the welfare of the Central Americans.

Scientific findings

Emission scenario

The two emission scenarios selected for developing the climates scenarios for Central America are the marking scenarios A2-ASF and B2-MESSAGE. These regional emission scenarios allow for the analysis of the main associated tendencies for the region and help to better understand climate variations and impacts and prioritize the establishment of proactive adaptation options. Analysis of emissions scenario components must be conducted keeping in mind the existing differences between individual Central American countries in terms of GNP, productivity structure, population growth, as well as political and social situation.

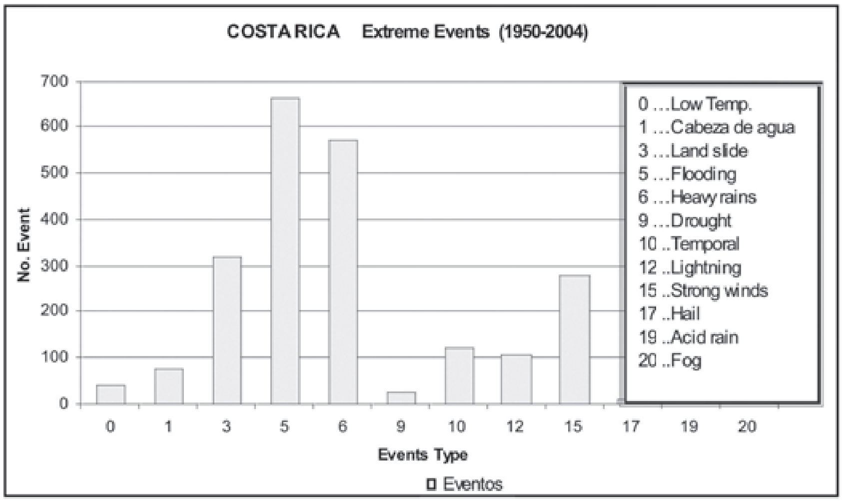
Climate change scenarios

The HAD2TR GCM model was found to be best suited for determining future temperature and precipitation for the Central American region using the A2 and B2 emission scenarios. Model projections show an increase in temperature between 0.3° C in 2010 to 3.4° C in 2100. The largest increases occurred during the boreal summer (June-August) and the lowest occurred during winter (December-February), with a secondary minimum during April. In geographical terms the magnitude of the change in temperature is slightly larger in the Southern sector of Central America (Panama and southern Costa Rica) than in the North (from Belize to the North of Costa Rica), in particular after 2050. In the case of precipitation, the temporal and spatial variation is more irregular. A decrease in rainfall is observed for regions north of Costa Rica and an increase is observed for regions South of Costa Rica. In terms of magnitude, an average increase is observed in time for all cases.

In the development of climate change scenarios a linear relationship is assumed between global climate and regional climate, which in reality is not probable and does provide some disadvantages in the accuracy of future climate projections.

Cold air pushes (EF) from mid and high latitudes and the occurrence of extreme events along the Caribbean of Costa Rica

A "cold push", is the movement a relatively cold and dry air mass from mid and high latitudes toward Central America and the Caribbean. The occurrence of cold air pushes (EF) that reach Central America and the Caribbean are concentrated during the December-February period. It was observed that the greater is the number of EF per season, the larger is the rainfall recorded. Such cold air pushes have been associated with the occurrence of extreme events and 41 out of the 69 EF that reach Northern Panama were associated with the occurrence of extreme events along the Costa Rica's Caribbean. Of the 2.7 extreme events produced every season between 1975-2001, 1.6 were due to an EF and 1.1 were due to modified trade winds. Such extreme events due to EFs could potentially increase due to the impacts of climate change.



Source: Campos and Ortiz, AIACC LA06, 2006

Figure 6.1: Extreme events in Costa Rica for the period 1950-2004

Increased rainfall associated with climate change could lead to more frequent and intense flooding events along the Caribbean of Costa Rica and Panama which might affect the population and productive activities, in particular the banana production that takes place in a large part of this territory. This in combination with the impacts of extreme events due to EFs could further cause social and economic damage.

Climate change scenarios for Central America and water resources

An increase in temperature and decrease in rainfall in the northern portion of the Central American region as projected by climate scenarios could, in combination with the impacts of other phenomena such as El Nino events, result in severe water deficits. In the Southern portion of Central America, the increase in precipitation could create flooding issues. This has implications for agricultural irrigation as well as for the availability of water for consumption especially for the revenue generating tourism industry. This could potentially cause water resource conflicts in the future and would requrie integrated development planning.

The increase in demand and the potential reduction of supply due to climatic change, together with the role of extreme climatic events and the poor quality of water in the Central American countries, puts the region in a state of high vulnerability; hence, there is an urgent need for the development of mechanisms and options that will allow for the improvement of the current conditions and also for adaptation to future water resource availability conditions.

Adaptation options for the banana sector to climate change and extreme events along the Caribbean of Costa Rica

Due to the impact of cold air masses from high latitudes and the associated flood occurrences that affect the banana sector, a study was done to assess this sector's situation with respect to such events, and to determine measures and strategies that could be applied keeping in mind the added impacts of climate change. This is the first such study of its kind and it is hoped that it will encourage similar studies for other sectors of export importance for the region such as coffee, sugar cane and rice, which also serve as an important source of employment for a large number of people.

An important limiting factor in the development of adaptation strategies for the banana sector was found to be the unavailability of information on practices, composition of operations, characteristics of production, product allocation, commercialization, productive structure, and management. This was largely due to confidentiality requirements within the sector for the purpose of protecting their products from competitors. As a result very little response and cooperation could be obtained from this industry for the development of adaptation options. Therefore knowledge systems, systematic mitigation options, and policy promotion for reducing the effects of climate change and extreme events that produce flooding, are presently in a very premature stage for this sector. Some cooperation was obtained from the National Banana Corportation (CORBANA), which was helpful in enabling work on this subject. Besides, the composition of this sector is also quite heterogeneous and internally divided, which presents further challenges in the implementation of sectoral adaptation policies. Government involvement at the moment is also quite minimal.

An evaluation of the adaptation capacity of this farming community to climate variability, mainly drought was conducted based on particular aspects at the watershed level pertaining to strategies and technologies in agriculture, forest and livestock, other socioeconomics alternatives and the communication strategy and awareness levels. Certain weaknesses were observed in the present system of watershed management and it was found that some technologies such as the use of green manures, use of alive and dead barriers and systems of water harvest and storage are not widely used. Strategies such as irrigation and fruit plantations were more commonly used depending upon the soil capacity and water availability. It was also observed that in order to effectively adapt to climate change there is a need for better information dissemination, increased awareness and increased capacity building among the farming community. The role of the government is perceived as a potential window of opportunity to help initiate climate change adaptation measures for this sector.

Capacity building outcomes and remaining needs

The AIACC project has successfully created strategic alliances with several environmental organizations working in the area of climate change. It has collaborated with the Freshwater Ecosystem Program for Mesoamerica for the IUCN and developed a publication on Climate Change and Freshwater Ecosystems (IUCN-CRRH-UNA) with the collaboration of the Universidad Nacional de Costa Rica (UNA). Along with the IUCN and the Global Water Partnership (GWP), several AIACC platform studies have been developed, particular related to water resources, which are significant contributions to the capacity building process. Collaboration with the Tropical Agricultural Research and Higher Education Center (CATIE) has yielded a masters degree thesis on climate change adaptation methodology. The results of this work are to be implemented shortly by the Regional Committee on Hydraulic Resources (CRRH) in other sectors like potable water, energy and tourism.

As a result of this project, the capacity of the University of Costa Rica and their Geophysical Research Center to conduct research on climate change has significantly increased. Masters degree students at this university are now able to work on climate modeling studies and the infrastructure available at the CIGEFI has sufficiently increased to allow for such studies to be undertaken for the entire Central America Region.

The study of the impact of climate on the productivity of the banana sector and potential adaptation options succeeded in enlisting the participation of this typically closed sector, especially via the CORBANA (Banana Corporation) and opened the possibility of future exchange of information on climate change and productivity. This is a very significant step in capacity building because for the first time this private, highly productive sector of Central America has directly participated in this kind of study. The project has also opened the possibility of future work with other private sector entities, not only in agriculture but also in tourism, energy and others.

Various other institutions also participated in this project activity and various seminars, consultations, visits, and interactions with all related actors were organized. It is necessary that capacity building for dealing with the impacts of climate must be continued in the future, incorporating recent knowledge and understanding about climate change.

National communications, science-policy linkages and stakeholder engagement

The Central American Integration System (SICA) is officially responsible for the implementation of the “Convenio Centroamericano sobre Cambio Climatico,” signed in 1993 by the Central American Countries for accomplishing the objectives of the UNFCCC. The specialized agencies for SICA on water and Climate (Regional Committee on Hydraulic Resources CRRH) and environment (Central America Commission on Environment and Development) are responsible for supporting and implementing national and regional initiatives, on mitigation, vulnerability reduction and adaptation to climate change. The AIACC LA06 project is one such initiative. This has succeeded in disseminating the results of this study at the highest political levels and a summary of study results will be presented for consideration at the Presidential and Ministerial level summits. The CRRH is also organizing at SICA an activity for the release of the Forth Assessment Report of IPCC and the results of the AIACC study will also be also presented.

The LA06 project has also successfully developed alliances with several large organizations working on climate change issues such as IUCN, GWP and CATIE as well as with the private sector entities, which were previously not a part of this process. Entities from these organizations along with the project participants of the LA06 project and the faculty and students from the University of Costa Rica will be contributing to the development of the National Communications for this region.

Policy implications and future directions

The AIACC-LA06 has contributed to the decision making process of the highest political organization in the region, the Central America Integration System (SICA). The findings of this study in terms of climate impacts and adaptation strategies are not only pertinent to the agriculture sector but also stress upon the need for adaptation among the other sectors of the economy. It is suggested that national policies of countries in Central America must incorporate specific policies related to climate change not only as an environmental strategy but also as a part of their economic, commercial and social strategies. This would greatly contribute to the achievement of this region's goals for sustainable development. This is especially important given that, natural disasters and extreme events could prove to be significant barriers in this process. Therefore adaptation to the changing climate must be made a priority. Costa Rica is one country that is already making an effort to include climate change as one of the national priorities to be addressed.

It can be suggested that the AIACC LA06 project has created a window of opportunity for the implementation of Central America's climate change agenda, wherein government, non government, academic and private sector actors can come together and share information and expertise to make regional development sustainable.

6.2 Global Climate Change and the Coastal Areas of the Río de la Plata (LA26)

Summary Information

Country: Argentina and Uruguay
Principal Investigator: Vicente Barros
Administering Institution: UBATEC SA, University of Buenos Aires, Buenos Aires. Argentina.

Research problem and objectives

The Plata River is a fresh water estuary with unique features (Figure 6.2). It is already 50 km wide at its source and broadens to 200 km at the outer limit. The salinity of the estuary is maximum at the outer limit of the river, reaching oceanic values. The dimensions and shape of the Plata River together with its very slight slope of the order of 0.01 m / km favor the propagation of astronomic and storm surge tides from the ocean without discontinuities. Because of the progressive reduction of the estuary's depth and width towards its interior, these tides increase in height as they move towards its interior.

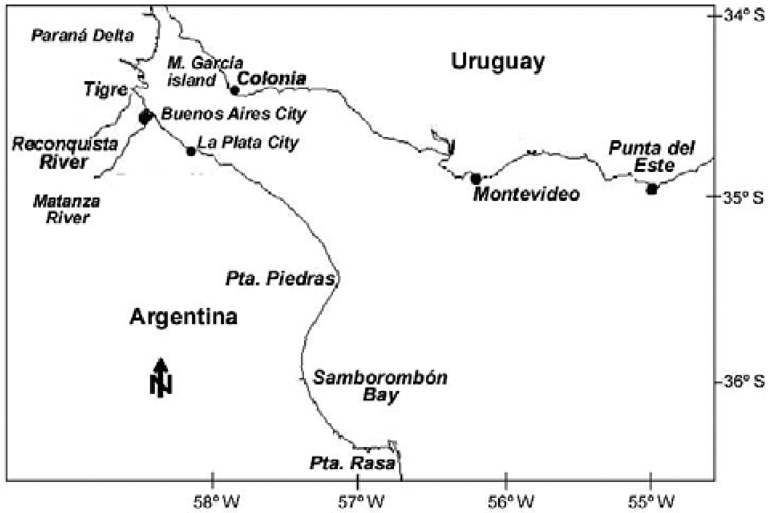


Figure 6.2: The Plata river estuary

Strong winds from the southeast drag the waters towards the Plata River and produce very high levels, especially if they coincide with high astronomic tides. These events are locally known as *sudestadas* and cause floods along the low coasts of the Argentine margin. The typical duration of the flood caused by the sudestadas ranges from a few hours to 2 or 3 days. These storm surges are higher on the Argentine coast than on the Uruguayan one due to the effect of the Coriolis force, and because of the lower height of the Argentine coast. The more affected areas are the south Samborombón Bay, the low coasts of the southern Great Buenos Aires, and the zones near the outlets of the Riachuelo and of the Reconquista River, as well as the front of the Paraná Delta.

The coasts of the Plata River house near 14 million inhabitants, most of which live in the Buenos Aires Metropolitan region. Sea level rise brought on by Climate Change could result in an increase in the frequency of storm surge floods in this densely populated area. To examine this important concern, this project activity attempted to answer the following questions: How many people are currently affected by recurrent floods and how frequently? What are their adaptation capabilities? What is the damage to infrastructure and to real-estate property caused by these floods? Considering likely sea level rise in the twenty first century, how will it change the return periods of floods and consequently how much additional population is likely to be affected? How and where will the social vulnerability to floods worsen and by how much are the costs of these events likely to increase? Finally, what is the estimated the number of affected people in areas enduring floods? In brief, the objective of the Project was to assess the social and economic vulnerability to water level rise along the Argentine coast of the Plata River as a result of Climate Change.

Approach

Mean and storm surge levels were simulated by a two-dimensional hydrodynamic model with high spatial (2.5 km) and temporal (1 minute) resolution. The model was calibrated to astronomical tides and storm surges for the period 1990-1999 and outputs verified. After confidence in its capacity to reproduce the basic features of storm surges was acquired, the tuning of the model allowed the estimation of maximum tide values of flood events along the coast of the Plata River, thus overcoming the lack of basic data.

For calculating the reach of floods over land, for each level on a point of the coast, the surrounding area that is below this level on the land was assumed flooded. This method does not consider the backwater effect on the tributaries, and thus underestimates the flooded area near their mouth. A new digitized model of the land altitude was developed with 0.25 m vertical and 1 km horizontal resolution, using field measurements taken with a differential GPS and data from satellite interferometer radars. This data was complemented with the information of pre existing lower resolution topographies and with existing altitude measurements at certain points that were taken at request of the Buenos Aires City.

The assessment of social vulnerability was made through the integration of the physical and social information in a geographical information system (GIS). This system facilitated the estimation of the affected population, the public service infrastructures and the real-estate damages under different possible scenarios. The social information for current conditions was taken from the 1991 census and the economic information was estimated, in case of the infrastructure of services, by the technical data provided by companies. Real-estate values were estimated by current commercial values considering nine different zones of different socio economic status.

For future scenarios, socioeconomic conditions were considered constant in time, which is clearly a very strong simplification. On the other hand, water level conditions were estimated using sea level and climate values of the A2 scenario reported by the IPCC (2001a) as forcing entries into the hydrodynamic model of the Plata River estuary. Information and old maps of the Paraná delta since 1608 to the present were compiled to document the delta advance in the last 200-100 years.

The number of persons affected by floods was estimated from the spatial population distribution and the flooded area corresponding to every return period. Information on social indicators was only available at district level. Therefore, the social structural vulnerability, which is measured from the social economic indicators, was estimated at district scale, which is only an approximation of its spatial distribution. The indicators that are representative of the response capacity to cope with the different stages of the flood emergency were combined to develop a social index of structural vulnerability. These indicators include aspects of demography, quality of life and productive and consumption processes.

An index of exposition to floods was calculated from the return period of floods calculated for every cell of 1 km^2. This was used to calculate the index of social vulnerability to floods by combining it with the structural vulnerability index. The final index of social vulnerability ranges from 1 to 100 in the area of the study.

The evaluation of current and future costs includes real estate and the infrastructure of water supply, sewage system, power generation plants, highways and railroads. For each of these systems, incremental costs were evaluated as a function of the level of rise of the Plata River over its current value. Damage to real estate for each event was estimated as a percentage of its current real-estate value, which includes the direct costs of repair, loss of furniture and costs of depreciation. The areas under potential flood threat of present or future flood were classified in 9 different zones according to their current features and real-estate value. Real estate cost in each zone was calculated according to the flooded area of the zone and the real estate value.

In order to estimate the mean annual value of losses due to floods for the current and future scenarios, the sum of the damages to different components of infrastructure and to both public and private real-estate for each event was calculated and this was used to estimate the annual average cost based on the number of such events. Two cases studies were conducted, in the La Boca neighborhood in the City of Buenos Aires and the Avellaneda Municipality in the Metropolitan Area of Buenos Aires, to gain insights into the social and institutional responses to recurrent floods during the past and present. In both cases, their long tradition of dealing with recurrent floods gave indications on the manner in which the population of Great Buenos Aires may respond when major adaptation will be required. Interviews were conducted with officials in charge of the institutions that deal with the different aspects of floods (planning, disaster response, etc) as well as with key informers.

Results

The mean Plata River level rise is expected to be a few centimeters greater than the sea level rise because of the wind rotation to the east, which incidentally is already happening. For the same reason, the level of rise will be higher for the Uruguayan coast than the Argentine coast and greater towards the interior of the River.

The areas at risk of enduring floods during this century along Plata River coasts are presently very small. If the spatial distribution of population in the metropolitan area of Buenos Aires does not change too much in this century, then the number people likely to be affected by permanent flooding would be very small. Therefore, the assessment of climate change risk in the coastal areas of metropolitan region of Buenos Aires is more a matter of dealing with the increasing inland reach of storm surges than with permanent flooding.

The areas that are presently more exposed to storm surge floods are the coast of the Great Buenos Aires to the south east of the city, part of the district of Tigre and the coast of the Samborombón. According to the SRES A2 scenario, the social vulnerability to floods is likely to become worse this century along the margins of the Reconquista and Matanzas-Riachuelo rivers and to the south of the Great Buenos Aires in zones relatively far from the coast.

In a scenario of 0.4 m sea level rise for the 2070 decade with a modest 1 percent annual rate increase in population, without considerable changes in its distribution and no new defenses built, the population at risk of some flood (recurrence every 100 years) is projected to amount to about 1,700,000, more than three times the present population in such conditions. Approximately 230,000 people are likely to face the risk of flood every year, six times the population that currently suffers such recurrences.

Assuming no adaptation measures in place and no significant change in real estate property, losses for the period 2050-2100, including real estate damages and the incremental operational costs of coastal facilities, would range from 5 to 15 billion US dollars depending on the speed of the sea level rise. The majority of this cost would originate from real-estate damage. Although this scenario is unlikely because some sort of adaptation measures are expected to be in place, these estimates allow for the assessment of the economic burden of Climate Change in the Metropolitan region of Buenos Aires in the absence of any action assuming only a single impact i.e. the increasing inland reach of the storm surges.

With respect to adaptation, in the areas subject to frequent flooding, the existence of informal alert networks among neighbors tends to diminish the vulnerability to floods. However, it is observed that, in these areas, the increasing number of new residents is reducing this collective cultural adaptation to floods. Another issue is that the present defenses against floods were designed without considering the future river level rise and may not be sufficient for future adaptation. The institutional response to floods, although following a similar organization pattern differs from one district to another in its functioning and coordination. In some cases the lack of cooperation between responsible institutions creates an additional source of vulnerability.

In the past the occupation of the small areas of very low lands was avoided. This adaptation strategy is presently being ignored, and current trends of occupying lands facing flood risk, by both very poor settlements and gated communities of upper middle class people does not favor the collective adaptation to present and future scenarios of recurrent floods.

Scientific findings

The hydrodynamic model of the estuary was used to perform the analysis of the sensitivity of the Plata River's reaction to the changes in the variables that determine its level, i.e., the sea level, the direction and intensity of winds and stream flows contributed by the main tributaries, the Paraná and the Uruguay rivers. Though winds cause the greatest variations in the estuary level by generating important tides and are also the major cause of the seasonal variations throughout the year, the model suggests that the foreseen sea level changes during the twenty first century will be the principal factor of change in the mean level of the estuary. The rotation expected in the mean winds from the northeast towards the east will also contribute to the increase of the mean Plata River level continuing the trend observed in the last 30 years, probably adding 5 to 10 cm in this century but this rise will be lower than the contribution of the sea level rise. The discharges from the tributaries, as in the past, will only contribute a few centimeters in cases of exceptional discharges and only near the delta front.

Capacity building outcomes and remaining needs

Active participation in the AIACC Workshops and in other training activities contributed to the capacity building of Project participants. Other relevant activities directed to increase awareness in the society were: a Master's level course at the University of La República, Uruguay in cooperation with the Project ¨Assessing Global Change Impacts, Vulnerability, and Adaptation Strategies for Estuarine Waters of the Rio de la Plata¨. This cooperation was extended to two courses for journalists in Buenos Aires and Montevideo. The Project supported the thesis of highly qualified students, which made important contributions to the Project. A new and very important experience for most of the project investigators was the work with stakeholder groups.

Given that climate trends in Argentina were significant during the last decades, it is necessary to begin implementing or in some cases improve the current autonomous adaptation and consequently, it is necessary to build additional capacities in the study and development of adaptation to climate change.

National communications, science-policy linkages and stakeholder engagement

The Project results provide the basic inputs for the vulnerability study of the coastal area of the region of Buenos Aires, which is an enabling activity for the second National Communication of Argentina to the UNFCCC. This task has been assigned to the Argentine co-investigators of this project.

The Secretary of Environment and Sustainable Development has developed the Environmental Agenda for Argentina based on technical reports and workshops. The climate change issue was addressed in 14 reports of which 2 dealt with the Plata River coast and were based on the Project results.

The project aimed to achieve an inter-consultation relationship with selected stakeholder organizations. This task focused on the evaluation of, the project scope, development and results by the stakeholders. Institutional actors were consulted both as privileged users of the information produced by the project and, as key informants due to their expertise and involvement in the issue of floods and their management. The methodology applied was the introduction of a communicative process, with the intention of going beyond isolated consulting, establishing rules and creating continuous mechanisms of association and interchange with stakeholders during the development of the project

Policy implications and future directions

The results of the Project and its dissemination among stakeholders provide the basis for the development of regulations for the coastal area that favor the use of activities compatible with adaptation to recurrent floods. The lack of consideration of climate change in the planning and design of structural works that prevailed until now is likely to be abandoned as specialists and stakeholders become aware of the findings of this project. It is important that projects this be undertaken to address the climate driven extreme events in the context of climate change and other changing factors in other systems and regions of the country.

6.3 Climate Change and Variability in the Mixed Crop/Livestock Production Systems of the Argentinean, Brazilian and Uruguayan Pampas (LA27)

Summary Information

Country: Argentina, Brazil and Uruguay
Principal Investigator: Agustin Giménez
Administering Institution: Instituto Nacional de Investigación Agropecuaria (INIA), Montevideo, Uruguay

Research problem and objectives

Numerous studies have been conducted in the study region to assess the impacts of interannual climate variability and long-term climate change on agriculture. Work on the development and establishment of agricultural decision support systems that account for future climatic conditions has recognized that alternative management options that are feasible and reasonable from the perspective of stakeholders are important. Therefore simulation models have been employed to identify optimum crop management options that reduce potential negative impacts of climate change and variability on crop production (e.g., sowing dates, cultivar characteristics, fertilizer use, etc.). However, these options to do not address the pasture component of the mixed systems of the Pampas, where crops and livestock production are integrated in the same farm.

Crop/livestock (mixed) systems are the most economically important livestock systems in Latin America. The entire crop production in Uruguay is integrated with livestock with a rotation of 3-4 years of annual crops and 3-4 years of sown pastures for beef, milk and wool production. The Argentinean Pampas region can be divided into three sub-regions with different farming systems: one mainly used for annual crop production (North of Buenos Aires, South of Santa Fe and Southeast Cordoba) covering 7.5 million ha; a second one used mainly for livestock production (Salado river basin) with 9.5 million ha; and a third sub-region with mixed crop-livestock systems which covers 38 million ha, accounting for the largest proportion of the animal population in the Argentinean Pampas.

The mixed production systems of the Pampas are characterized by mild climatic conditions, which can allow for annual double cropping, fertile (although often degraded) soils, and the co-existence of livestock and annual crops in the same farm. This allows farmers a very high flexibility in modifying management practices to better adapt to climate variability and climate change. On the other hand, this also creates challenges for research since tools to improve planning and decision making must consider a very wide range of possible activities, mixes and interactions.

The objective of the proposed research was to further develop capacity and to establish, use and maintain an agricultural systems network in the Pampas to assess the impact of climate change/variability and develop adaptive responses for the mixed grain/livestock production systems.

Approach

The premise of this research is that an effective way for assisting agricultural stakeholders to be prepared for and adapt to potential climate change consists of helping them better cope with current climate variability. One of the advantages of this approach is that it provides immediate assistance to the public and private agricultural sectors for dealing with current climate variability in addition to preparing stakeholders for possible future climate scenarios.

Our research activities integrated crop and pasture simulation models with climate change scenarios to assist planning and decision-making at the farm level. This system was used to assess the impacts of climate change/climate variability on farmers' income and to study the vulnerability of different components of the mixed production systems. The system can now be used to identify whole-farm adaptive measurements for global climate change scenarios and impact assessment of policy decisions.

Climate change scenarios were created using two methods: (a) projecting the trends observed in climate in the last 70 years using a weather generator (LARS), and (b) using a GCM (Hadley center – HADCM3).

Scientific findings

Climate Change Scenarios

Regression analyses performed on 1930-2000 climate data, and the comparison of 1931-1960 vs. 1970-2000, revealed increases in rainfall (especially in summer and spring), decreases in maximum temperatures in summer (and no change in the rest of the seasons), and increases in the minimum temperatures throughout the year.

The absolute maximum temperatures in 2000, in the sites showing significant changes were on average 4.3^{o}C higher than in 1930 (range: 1.5 to 12.3^{o}C). The absolute minimum temperatures increased an average of 1.9^{o}C (range: 0.9 to 3.5^{o}C) during the period 1930 – 2000. These changes were only observed in Argentinean and Uruguayan locations while no changes were seen in the Brazilian sites.

During the study period (1930 – 2000), the frost regime became milder in some Argentinean and Uruguayan sites i.e. frosts start later and end earlier with higher temperatures. This was not observed in the Brazilian locations.

Climate scenarios projected with the two methods used in this study were considerably different. In both cases rainfall increased (especially in spring and summer) but LARS projected much larger changes than HADCM3. Both methods projected increases in minimum temperatures, but opposite results for maximum temperatures (LARS projected decreased values in summer and no changes in the rest of the year, and HADCM3 projected increases throughout the year)

Impacts and Vulnerability

The increased temperatures projected by the climate change scenarios used in this study are expected to result in shorter growing seasons and consequently in lower soybean and maize grain yields. However, this negative impact could be greatly mitigated by adjusting the crop sowing time to earlier dates. This would allows crops to benefit from the expected increase in rainfall during the maize and soybean growing seasons and the expected direct CO_2 effects on soybeans resulting in increased grain yields for all future scenarios simulated by HadCM3.

According to scenario results soybean would greatly benefit under the enhanced CO_2 environment and the climatic conditions projected by HadCM3 for 2020, 2050 and 2080 for SRES A2 and B2 scenarios. However, crop responses to CO_2 enrichment under field conditions are yet to bet fully understood. Most experiments have been carried out in controlled or semi-controlled conditions and there are still uncertainties related to interactions among crops, weeds, pests, water, nutrients, etc. under climate change.

The expected direct effects of CO_2 on crops in the long term are still uncertain. Recent research suggests that the initial stimulation of photosynthesis observed when plants grow at elevated CO_2 may be counterbalanced by a long-term decline in the level and activity of photosynthetic enzymes as plants acclimate to their environment, an event referred to as 'down-regulation' which has not been included in the crop models used in this study.

The impact of the climate change scenarios used in this study on the sown pastures of the Pampas was much smaller than that observed for maize and soybeans. Two likely explanations for this differential behavior are: (a) pastures grow throughout the entire year and during 3 or 4 consecutive years (annual crops grow for 4-5 months) and this much longer growing period could allow for some "buffering" capacity for reacting to possible unfavorable climate conditions; and (b) the harvested yield in annual crops, is the result of a reproductive stage (flowering, grain filling, etc.) while in the case of pastures, the harvested yield corresponds to the vegetative growth (total biomass).

In all the locations studied, *Fusarium* head blight (FHB) was greater under the climate change scenario than historically. The high risk index of FHB was probably due to the presence of more rainy days during September-November period in the climate change scenario. If confirmed, this could have a significant impact on wheat production and mycotoxin contamination for this part of the world

Adaptation

Adaptive measures for maize and soybeans

When an increased CO_2 concentration is considered, adaptive measures including optimal planting dates and nitrogen rates would result in maize mean yield increases of 14 percent, 23 percent and 31 percent for 2020, 2050 and 2080 respectively under SRES A2, and 11 percent, 15 percent and 21 percent respectively, over the same period, under SRES B2. The corresponding figures for mean soybean yields were: 35 percent, 52 percent and 63 percent for 2020, 2050 and 2080 respectively under SRES A2, and 24 percent, 38 percent and 47 percent respectively, over the same period under SRES B2.

In the case of current CO_2 concentrations, the study results suggest that simple measures such as changes in planting dates or N rates would not be sufficient to compensate for the losses in maize yields under climate change scenarios. When supplementary irrigation was applied, an overall yield increase was observed with changes in yield close to 20 percent under all scenarios. Soybean yields, in the absence of any adaptation measures decreased under all scenarios (1-12 percent). Changing planting dates led to a weak increase in yields (2-9 percent) only for 2020 and 2050. The addition of supplementary irrigation strongly reverted this situation increasing soybean yields between 30 percent (A2 2080) and 43 percent (A2 2020). Thus, rather simple adaptation measures could be beneficial for soybeans, even if CO_2 effects are not considered.

Improving applications of ENSO-based seasonal rainfall forecasts in agriculture considering South Atlantic Ocean (SAO) surface temperatures

- Upper quartile SAO anomalies in August and September were consistently associated with mean or high maize yield levels, even under La Niña or Neutral years.
- Complementing ENSO phases with warm SAO led to an increase in the economic value of ENSO-based climate forecast by 5.4 percent.
- Differences in optimal planting dates between El Niño and warm SAO years can be attributed to differences in rainfall distribution.

These results could contribute to improving the applications of ENSO-based seasonal forecasts.

Capacity building outcomes and remaining needs

Capacity building outcomes

- New regional climate change scenarios locally adjusted via downscaled GCM runs for the region and through the use of statistical techniques (with a weather generator) were developed.
- Crop and pasture models able to simulate the mixed crop/livestock production systems of the Pampas were calibrated and tested.
- Climate scenarios and crop/pasture models were linked in a simulation platform useful for conducting scenario analyses of mixed crop/livestock systems and their responses to climate change/variability and management intervention.
- An agronomic database characterizing the mixed crop/livestock production systems of the Pampas including soil information, crop and pasture management practices and rotations was developed.
- Links were established between the scientific climate community, agricultural researchers, agricultural practitioners and policy makers to improve the planning and decision making processes in the public and private agricultural sectors.
- An established generic methodology was developed for creating agricultural systems networks that can be adapted to other environments and production systems for comparing possible adaptive responses at the farm and policy level against the background of a variable and changing climate.
- A cadre of scientists was trained in the development and implementation of methodologies to address issues of vulnerability to climate and thus assisting farmers and policy makers improve their planning and make better management decisions.

Remaining capacity building needs

- Regional climate change scenarios locally adjusted via dynamically downscaled GCM runs for the region need to be developed.
- Results of specific studies on the impact of climate and present management practices in the mixed crop/livestock systems of the Pampas, on crop, pasture and animal productivity levels and

stability; the resource base (runoff and nutrient leaching); and the regional water resources; are required.

National communications, science-policy linkages and stakeholder engagement

National Communications, Science-Policy Linkages

This AIACC project contributed to the Second National Communication of Uruguay, submitted in 2004, which included a section entitled: "Assessing the impacts of Climate Variability and Climate Change on the Mixed Crop-Livestock Systems of the Pampas in Argentina, Brazil and Uruguay". One of the project investigators, Walter E. Baethgen, presented a paper entitled "Climate Change Adaptation and the Policy and Development Agendas of Developing Countries" at a side event of the 10th Session of the Conference of Parties to the United Nations Framework Convention on Climate Change entitled, "Science in Support of Adaptation to Climate Change, Recommendations for an Adaptation Science Agenda and a Collection of Papers." Project investigators also contributed to the IPCC Fourth Assessment Report in the following capacities:

- Working Group II: Chapter 13 (The Latin America Region) - Coordinating Lead Author: Graciela O. Magrin; Contributing Author: María I. Travasso; and Reviewer: Walter E. Baethgen.
- Working Group II: Chapter 17 (Assessment of Adaptation practices, options, constraints and capacities) – Reviewer: María I. Travasso

Stakeholder Engagement

Uruguay:

- 1st National Workshop AIACC, INIA Tacuarembo, Tacuarembo, Uruguay, June 30, 2004: To disseminate and discuss information about climate variability and climate change, and possible impacts on cattle beef production systems in Uruguay. More than 40 individuals from different stakeholder and research organizations participated.
- 2nd National Workshop AIACC, INIA La Estanzuela, Colonia, Uruguay, August 18, 2004: To disseminate and discuss information about climate change results from this project, and possible impacts on crop production in Uruguay. More than 100 individuals from different stakeholder and research organizations participated.

Argentina:

- 1st National Workshop AIACC, Federación Argentina de Acopiadores, Buenos Aires, Argentina, October 7, 2004: To disseminate information related to climate variability**.** Participants included members of Federación Argentina de Acopiadores, Bolsa de Cereales, Fundación Producir Conservando and Interlink Sur Biotechnologies.
- 2nd National Workshop AIACC, Bolsa de Cereales de la República Argentina, Buenos Aires, Argentina, October 27, 2004: To disseminate results obtained under AIACC activities related to climate changes over the last century and climate variability in the Pampas Region. Participants included more than 200 people, representing farmers' associations, policy makers, agribusinesses, and the Secretary of Agriculture.

Brazil:

- 1st National Workshop AIACC, Secretaria da Agricultura do Rio Grande do Sul, Porto Alegre, Rio Grande, Brazil, October 7, 2004: To disseminate and discuss information about climate variability and climate change, and possible impacts on crop production in Southern Brazil. Participants included 30 individuals from different stakeholder groups and research organizations.

Policy implications and future directions

The results of this project are based on possible future climate scenarios generated using GCMs or projecting the observed trends in climate variables over the last century. These scenarios intrinsically have a large degree of uncertainty and all communications (publications, presentations, discussions, etc.)

resulting from the project activities to both, scientific audiences as well as to policy/decision makers make note this uncertainty in order that it may be factored in decision making.

Implications for Soybean production

The study results suggest that by establishing rather simple adaptation measures soybean would benefit from the projected climatic changes. The continuing expansion of this crop observed in the study area during the last few years could however continue to put at risk the sustainability of agricultural systems. Soybean is a high nutrient extractive crop with a low level of crop residues, and therefore, its monoculture leads to negative nitrogen (N) and carbon (C) balances. There is therefore a need to establish management practices that help to preserve natural resources such as adequate crop rotations (including using grasses as cover crops and a higher proportion of corn and wheat in the rotation).

Other alternative measures could be related to the destination of crop production. Assuming that the trend to increase annual crop production will continue in the future, regardless of climate change, promoting the so called "transformation in origin" would contribute to both, the sustainability of agricultural systems and economic returns. "Transformation in origin" means that a part of the production (for example of maize) remains at the place where it is produced and is used to feed animals or for local industry, thus adding value to the primary product. This contrasts with the traditional sale of grain as a commodity, which often implies important costs of transportation to ports and fiscal retentions, among others. Assuming that half of the maize production is transformed in origin, economic benefits could be more than duplicated.

Implications for the mixed annual crops / pastures systems

Our results also suggest that the pasture component of the mixed systems is much less affected by any of the climate change scenarios used in our research. Thus, in addition to the well-known risk reduction resulting from the diversification of a production system, the pastures would contribute to the system in two major ways: by decreasing the income variability under climate change scenarios, and by improving the C and N balances of the entire production system (as discussed above).

6.4 Vulnerability and Adaptation to Climate Variability and Change: The case of Farmers in Mexico and Argentina (LA29).

Summary Information

Country: Argentina and Uruguay
Principal Investigator: Carlos Gay
Administering Institution: Centro de Ciencias de la Atmósfera, Universidad Nacional Autónoma de México (UNAM), México

Research problem and objectives

Our understanding of the capacity of agriculture to adapt to climatic change has been constrained by the lack of the integration of crop and climate models with studies related to changing social circumstances in agricultural decision-making, which might take into account the full complexity of the systems under study. Recent case studies of agricultural adaptation have illustrated that non-climatic factors are often bigger determinants of individual farmers' strategies than climatic factors, throwing into doubt assumptions that farmers will necessarily and autonomously respond to climate signals and pursue optimal strategies - see, for example, Brklachich *et al*, 1997, Ziervogel, 2005. This situation is particularly observed when high losses in agricultural activities are reported in those years with "normal" climate conditions (Conde *et al*, 2006). Thus it is critical to understand how the specific social and environmental context of production influences strategic choices of farmers, and why some farmers and some farm systems may be more prepared to adapt to climatic changes than others.

This project studies the strategies used by different types of farmers in Mexico and Argentina for adapting to multiple uncertainties originating, on the one hand, from changes in the frequency, intensity or duration of extreme climatic events (which might be associated with a climate change trend), and, on the other, from dramatic socioeconomic changes associated with the embrace of neoliberalism in the Americas (O'Brian and Leichenko, 2000). While farmers in both countries are being exposed to similar processes of economic globalization in the context of high climatic risk, these processes have been translated into distinct national and sector policies.

Using selected farm types as the unit of analysis, the main objective was to answer the following research questions: How are broad-scale socio-economic and climatic processes of change in Mexico and Argentina, translated into region and sector-specific policy and institutional reforms, affecting the vulnerabilities of different types of farm systems and their capacities to adapt? What are the implications of particular agricultural and water policy reforms for the production strategies of different types of farmers, and what is the significance of these strategies in terms of enhancing or diminishing the vulnerabilities of farmers to climatic risk and their capacities to adapt to such risk? How can existing water and agricultural institutions and decision-makers make better use of climate research? How can adaptation capacities be enhanced within the context of current policy trends?

Approach

Climate Analysis

Observed changes in rainfall and temperature patterns and their impacts on agricultural activities were documented for both countries, particularly during El Niño/Southern Oscillation (ENSO) events. Historic climatic events were analyzed using "climatic threat spaces", where anomalies of temperature and of precipitation where used to visualize those conditions that might have impacted the agricultural sector. The years of strong ENSO were shown in the "climatic threat spaces", and the possible increases (decreases) of climatological parameters during those years were determined, and presented to key stakeholders, so that the story associated with those events could be reconstructed.

Responses during strong ENSO events and its impacts were also documented using in depth interviews and other sources of information (newspapers and "grey" literature). Simple characterization of cultivars' (maize, coffee, sorghum) temperature and precipitation requirements were attached to the "climatic threat spaces", in order to account for the possible events of climatic anomalies with respect to specific crops, during different growing stages.

Climatic anomalies were calculated using as a base scenario the period 1961 – 1990. Years of strong El Niño/Southern Oscillation (ENSO) events were selected using the multivariate ENSO index (http://www.cdc.noaa.gov/~kew/MEI/) paying special attention to extreme events at interannual time scales.

Climate change scenarios were generated using the outputs of atmosphere-ocean coupled GCMs (AOGCMs) and employing simple downscaling techniques. The simple climate models called MAGICC – Model for the Assessment of Greenhouse-gas Induced Climate Change (Hulme et al, 2000), and a climatic database (SCENGEN) with the outputs of 4 GCMs was used. These scenarios were then included in the "climatic threat spaces" to assess the possible future impacts on the crops under study.

This study also explored possible changes in climate variability under climate change conditions in addition to other numerical experiments. These methods were used to demonstrate that scenarios that reported relatively small changes could in fact produce important impacts i.e. the association of extreme events with the increase in the probability of harmful events.

Farmers and water managers were consulted from the beginning of the project to include their perceptions. Their participation provided guidance on the information needs and the role of particular climatic events and variables in their decision-making.

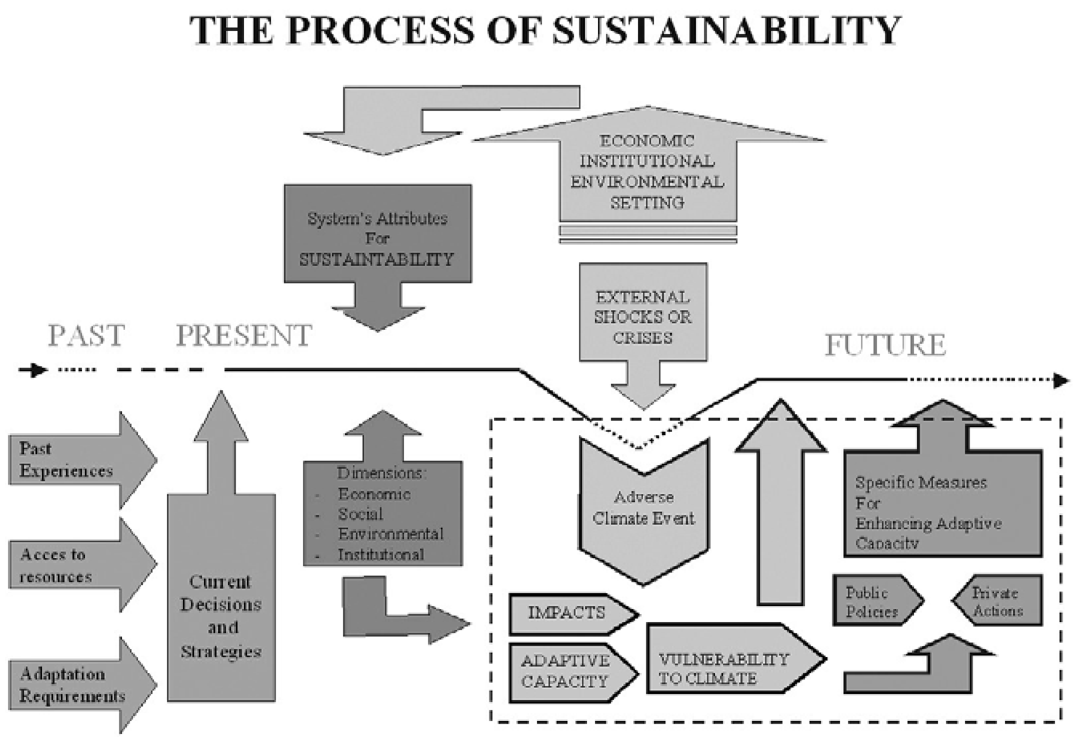
Farm-level and policy analysis

A political-ecology approach was adopted and the physical and social environments were assumed to be dynamic, evolving and highly uncertain contexts in which farmers make strategic decisions about their livelihoods (Scoones, 1998). The policy and institutional contexts of the agricultural sectors of the two countries were analyzed using primary and secondary literature, national and regional databases (population, economic and agricultural), interviews with key informants and review of regional newspaper and popular media. This analysis was used to understand the limitations and opportunities for adaptation and adaptive capacity building in the case studies and to explore the production of social vulnerability through development processes.

The institutional analysis was complemented by a farm-level survey implemented in three regions: four communities in south of Cordoba province (Argentina); *municipio* of González, Tamaulipas (Mexico); and two communities in Coatepec, Veracruz (Mexico). The survey instrument was designed to evaluate farm-level adaptive capacities and sensitivities to climatic and non-climatic shocks. The survey data was then analyzed descriptively, and indices for sensitivity and adaptive capacity were created for each of the case studies. These indices were then analyzed together to determine the vulnerability of the farm populations. This quantitative analysis of livelihood vulnerability was complemented with individual and group interviews with farmers to capture farmers' perceptions of risk and the importance of planning for adaptation. By attempting to understand the links between farmers' strategies to address structural changes in the economy and implications of those responses for their livelihoods, resources base and thus sensitivity to climate impacts, this project also attempted to use this vulnerability analysis to contribute towards the process of sustainable development in the study region.

This sustainability/vulnerability process is presented schematically in Figure 6.3. The red line represents the "level" of sustainability of the unit of analysis i.e., the agricultural household. At any given moment, this "level" of sustainability incorporates the accumulated past experiences of the household and the implications of that experience for present decisions and strategies. The social, environmental, or economic outcomes of these strategies in turn affect the future level of sustainability of the unit of analysis (household). This process is influenced by a number of factors, represented in the diagram by the series of boxes below (representing the micro-context of decision-making) and above (representing the global or exogenous context of decision-making) the black line running across the center of the figure. The four medium grey boxes on the bottom left represent the factors affecting the decision-making at the household-level. The light grey boxes above the black line represent the broader economic, institutional and environmental context of decision-making over which the individual household has little direct influence or control. These macro and micro factors affect households via sustainability attributes specific to the particular unit of analysis (illustrated in generic terms by the red boxes and as described by (Masera and López-Ridaura, 2000).

This light grey area is also a source of exogenous stressors that can affect the unit of analysis at any point in time, including adverse climate events. The dotted line in the lower right hand corner represents the scope of analysis of this project in which climate events and their impacts on the households are emphasized over other stressors in the sustainability analysis. The implications of climate events for the vulnerability of the households are determined by the sensitivity of the system and its capacity to adapt. The resulting vulnerability of the system can have an important impact on the level of sustainability of the household, as well as on the broader production system to which it belongs, thus affecting the future trajectory of its development. Interventions, either on behalf of public or private actors, to either reduce the sensitivity of the system or improve the capacities of households to adapt can counter-act this impact on sustainability and thus also influence the system's future development.



Vulnerability Assessment

Figure 6.3: The sustainability and vulnerability of agricultural systems

Scientific findings

Strong El Niño events in Mexico are associated in general with important decreases in summer precipitation and an increase in summer temperature (i.e. Magaña, 1999), which leads to important decreases in rainfed crop production (Conde et al, 1999). However the regions under study in Mexico (central region, Veracruz; southern region, Tamaulipas) are characterized by a small increase in summer called Mid-Summer Drought (MSD, known by farmers as the canícula) that obscures these processes and represents a different signal than the one expected in the country. Strong La Niña events, on the other hand, lead to important increases in summer precipitation i.e. Magaña, 1999, that represent the threat of flooding for the stated regions.

The central region of Veracruz has experienced increases in temperature (particularly minimum temperature) since the beginning of the twentieth century, consistent with the projected changes reported in the Third Assessment Report of the IPCC (2001b). However, frost is still a major concern for coffee production (Conde, et al, 2006). On the other hand, the southern region of Tamaulipas presents a possible decadal trend in precipitation, as observed in climatic data and newspapers reports of consecutive years of drought followed by several years of flood events.

In Argentina, maximum temperature has decreased particularly in the spring and summer while minimum temperature has shown an increase for all seasons. A consistent regional increase in precipitation during the summer and fall over the entire region with a well defined positive time trend has been observed. Increased precipitation is observed in the spring in the east and south and in winter in the west and south of the region. In addition to natural climate variability, the perceived increased variability is attributed to climate change. Climate variability and extreme events (floods, droughts, etc.) in the region are likely to create major uncertainties in agriculture, at least in the short term. Floods events may be exacerbated in the future in the flood prone zone in the south of the region since climate change scenarios indicate an increment in rainfall mainly during summer and fall but with the highest increases during April (the month with bigger floods in the area). Expected rainfall diminution in winter may jeopardize the possibility of double cropping although this effect might be ameliorated by the increments expected for fall. Climate scenarios indicate higher temperatures, which diminish the risk of frost but reduce the length of the growing season for summer crops possibly causing yield reductions.

Social vulnerability to climate at the farm-level is determined as much or even more by socioeconomic factors than simply by climatic variability and change. Particular sub-populations of the systems of study demonstrated that their risk management priority is adjustment to recent domestic policy changes and market liberalization, climate risk being a secondary consideration. Their adjustment strategies are therefore aimed at improving their livelihood stability in the face of such changes and may not address their climatic risk. Collectively, such response strategies may indirectly exacerbate the sensitivity of the case study regions to future environmental change due to potential environmental degradation and land use change. This study did not find that any particular system of production is necessarily more sensitive to climate impacts over other systems, but rather, in an economy favoring large-scale commercial production, family and smallholder farmers face economic difficulties that undermine their traditional risk management strategies and diminish their capacities to adjust to new shocks.

Methodologically, we found that comparison between very different farm systems is possible on the basis of similar factors creating vulnerability (i.e. global trends in economic development, similarities in the ideology driving domestic policy and similarities in the impacts of such policy), and compatibility in the generic attributes of adaptive capacity and sensitivity in each case study. However, we also found that the experience of vulnerability is necessarily site specific and vulnerability assessments need to be relevant to the particular governance and/or decision-making unit of the population under study. This means that the variables used to measure vulnerability in each case and the recommendations for enhancing adaptive capacities should be developed to reflect the important local social, economic and institutional characteristics of each case.

It was observed that in each case study farmers considered climate risk in their livelihood strategies, although their strategies were not determined by their perceptions of these risks (Gay et al, 2006). The measures that households currently take to reduce their sensitivity to or enhance their capacity to manage climate impacts are those that are most compatible with the type of economic strategy they are able to pursue given the range of available choices and opportunities. In attempting to identify deficiencies in current adaptive capacity, this study found that, despite the fact that neoliberalism implies a reduced role for the public sector, it is clear that there is a need for public sector support not only for enhancing farmers' capacities but also to ensure a more equitable distribution of resources and the sustainability of agricultural activities in the case study regions.

An integrated model was developed including climatic and socioeconomic variables (Gay et al, 2006), which showed that coffee production in the central region of Veracruz was based in areas of optimal climatic conditions, therefore small changes in these variables can imply decreases in coffee production. The model also showed that the most important economic variable was the minimum wage. Future changes in climate or/and economical conditions could greatly worsen the situation.

Capacity building outcomes and remaining needs

This project succeeded in raising awareness among appropriate sector agencies and stakeholders on the importance of issues associated with climate change, variability and extreme events through outreach efforts, and motivating support for the contributions of scientific research in decision-making. Not only did the project reinforce the development of innovative research methodology and interdisciplinary collaboration among the region's academic institutions, but it also evaluated the particular factors that make each region vulnerable, and provided a forum for dialogue on reducing this vulnerability through adaptive strategies. Building the regional capacity to sustain this dialogue in the academic community is a critical component of this project given that climate change research is a relatively new topic here with only a limited number of experts. Substantive contributions have been made by at least ten graduate student researchers in Mexico and Argentina and their involvement in the project has broadened the intellectual basis for debate on climate change policy and planning in both countries, as well as contributed theoretically to climate research in Latin American countries.

In Veracruz, for the climatic component of the project, two bachelor students (meteorology) completed their thesis; one master student (geography) completed her thesis and will begin her PhD at the same place (two master students utilized the climate change scenarios proposed by the AIACC team); and two students began their PhD thesis (geography). Project investigators, Dr. Adalberto Tejeda, Dr. Carlos Gay and Dr. Cecilia Conde served as advisors. In UNAM, one masters student (geography) and one bachelor's student (biology) have completed their thesis. Thus, there is now a "critical mass" of young scientists in the state and in UNAM that can help to develop further research in the region, and become part of a network that will collaborate on one ongoing project and submit future research projects.

In Tamaulipas, one geography student and one biology student are writing their bachelor's thesis; and one PhD student (geography) will complete her PhD thesis in 2007. Two students are expected to join Dr. Gerardo Sánchez and researchers in UNAM for an ongoing project and another project with the aim of involving local students to create a stronger research team in the region, is expected to be submitted.

However, no social science researchers (such as Dr. Tejeda and Dr. Sánchez) were involved in the AIACC project and no student thesis in this area was developed. It is expected that future research will involve more social scientists and regional experts and new funds and a stronger research network would be necessary to accomplish future goals.

In Argentina, the Project supported the masters' thesis of highly qualified students of which three are near completion as well as the thesis of two undergraduate students. About seven undergraduate and graduate students with different academic backgrounds made meaningful contributions to the project in areas of database completion, farmer and stakeholder surveys, collecting and processing information from different sources, field work activities, etc.

The involvement of different stakeholders (farmers, farmers' organizations, grain dealers, city mayor, city council, etc.) and mass media support for the project activities resulted in a broad diffusion of information on climate variability and climate change issues in the region creating a fertile and collaborative environment for the development of the project. Continuous reinforcement of these relationships (through workshops, conferences, brochure, booklets, web site, etc) would be necessary to improve current adaptive capacities and enhance future adaptation to climate variability and change in the region.

National communications, science-policy linkages and stakeholder engagement

Stakeholder workshops aimed at presenting project goals and methods and sharing perspectives and empirical knowledge contributed to the ongoing collaborative discussions between the Argentinean and Mexican research teams by helping to continually refine and improve upon the project's research agenda and identify new research foci. Discussions of results with both policy makers and stakeholder groups (i.e., farmers, water user organizations) led to the development of practical applications in water and agricultural practices and policy. In collaboration with stakeholder groups and governmental and non-governmental agencies in the regions of study, technical and information brochures have been developed to facilitate public education on vulnerability, climate impacts, and adaptation and to foster continued public support for climate change and variability research. Finally, dialogues with stakeholders and policy makers also allowed for the cataloguing of potential adaptive strategies for addressing climatic uncertainty and risk, which, although specific to the study regions, may provide the basis for action in other regions facing similar vulnerabilities.

For the Mexican case study, project investigators Carlos Gay and Cecilia Conde are a part of the research team that will elaborate the Third National Communication, and are also Contributing Lead Author or Lead Author in the IPCC's Fourth Assessment Report.

In the two final workshops for policy makers in Tamaulipas and Veracruz, several decision makers agreed to participate in future research. In Tamaulipas, directives and researchers from the Mexican Institute for Water Technology (IMTA) agreed to use the methodology proposed by Dr. Gerardo Sánchez, the AIACC collaborator and coordinator in the region. This is to be developed in an ongoing project (CONACYT – SEMARNAT) with a greater focus on adaptation measures. In Veracruz, Dr. Adalberto Tejeda organized the final workshop with the support of the Minister of Regional Development (Secretaría de Desarrollo Regional, SEDERE) and the participation of representatives of the Minister of Environment (SEMARNAT – Veracruz), regional farmer leaders, and directives and researchers from the University (UV) and the Center of Ecology (CE). Support for the project was garnered from SEDERE, UV and CE, with a focus also on possible adaptation measures. Unfortunately, farmers did not agree to participate in the final workshops held in Mexico. This was recognized as a lesson learned since the lack of a systematic and continued stakeholders' involvement could lead to misinterpretations of climate change information and can be a "mal adaptive" measure.

This research project will not be contributing to the Second National Communication to the UNFCC in Argentina since the centre of Argentine (the research region of this project) has not been included in that assessment.

Policy implications and future directions

On a regional basis, the project results have launched future research through the ongoing work of bachelor, master and PhD students based on this project. This has provided the basis for changes in the bachelor and postgraduate courses offered by the two universities involved in Mexico (Universidad Veracruzana and Universidad Autónoma de Tamaulipas) and in the Universidad Nacional de Río Cuarto in Argentina.

One of the ongoing projects is being supported by the Minister of Environment (SEMARNAT) and by UNAM. The new features in this project are mainly guided by the United Nations Development Program's Adaptation Policy Framework (APF, Lim, 2005).

Two specific projects focussing on Tamaulipas and Veracruz have been submitted (one approved). The first, (Sánchez et al, 2005) will address current and future availability of water in the southern region of Tamaulipas and possible adaptation measures. The second project (Castro et al, 2005; accepted) will focus on analysing and developing "environmental services" as a possible source of adaptation and will be developed in the central region of Veracruz. Forests sources and sinks of CO_2 are also to be studied, as part of a larger project for carbon sequestration. Finally, the results of this AIACC project are to be included in the Mexican Third National Communication to the UNFCCC.

The development of the Project in Argentina helped, on a regional basis, to increase awareness about climate change and climate variability and their impacts and to create consciousness at the institutional level. The capacity building created through this project set the Universidad de Río Cuarto as a reference institution for other institutions, organizations or individuals working on this topic in the region. A couple of new interdisciplinary research projects are being discussed and designed to be submitted for funding in order to move forward with the lessons learned from this AIACC Project. Discussion has also been initiated with researchers from two universities from nearby provinces to develop a network for permanent research, knowledge exchange and adaptation practises and experiences about climate change issues. New research pathways are being undertaken through collaboration with different stakeholder associations.

In addition the debate initiated in society through the project outcomes resulted in an increase in the solicitations to the government for the design of new infrastructure to deal with floods in the south of the area. New policies and regulations need to be developed to face increasing environmental risks in the area; the outputs of this Project will help to provide technical support to develop and implement these measures.

6.5 Vulnerability and Adaptation of Estuarine Systems of the Río de la Plata (LA32)

Summary Information

Country: Uruguay and Argentina
Principal Investigator: Gustavo J Nagy
Administering Institution: Facultad de Ciencias de la Universidad de la República (UdelaR), Montevideo, Uruguay

Research Problem

The Third Assessment Report (TAR) of the IPCC (2001b), referred to as TAR, identified two main environmental problems in South America: Land Use Changes and ENSO variability. The Rio de la Plata basin and estuary (see Figure 6.2) have been substantially influenced by human activities in recent decades and are highly sensitive to climate extremes and changing precipitation patterns. The Paraná-Uruguay system river water discharge increased by ~30 percent since 1961 with the consequent increase in river flow (Q_V) and decrease in salinity (Nagy *et al* 1997).

The natural vulnerability of the Rio de la Plata estuary to nutrient streams and its susceptibility to developing of eutrophication symptoms (see Nagy et al, 2002c) has increased due to the changing climatic and non-climatic conditions over the past fifty years. Within the frontal zone or estuarine front processes such as nutrient removal, in situ production of organic matter, and denitrification are estimated to be high (Nagy, 2000). The main symptoms of eutrophication are an increase of organic matter "expressed" as increased algal biomass (B) and production (P), oxygen stress, and Harmful Algal Blooms (HABs).

The increased variability in river flow varies by both the location and structure of the Estuarine Front (Figure 6.5), affecting the sites of reproduction and catch of fishes thus impacting coastal fisheries because of the changing accessibility of fishing areas (i.e. 1987-1988 and 1997-1999).

Primary objectives and expected outputs of the project updated to 2004.

Overall goal of the project was: i) to assess vulnerability of and impacts of/on the estuarine waters (hydrology and ecosystem), coast and resources of the Rio de la Plata estuary and ii) to plan adaptation strategies for coastal fisheries (Adaptive Control Information System-ACIS) in order to cope with climate variability and change, weather conditions and non-climate scenarios.

The key questions to be addressed were: a) How sensitive is the system to Climate Variability and Change? b) Is eutrophication related to Climate Change and Variability? c) Is the coastal fishery system sustainable under increased river flow variability? and d) Will the coastal zone be heavily impacted over the next few decades?

The secondary questions to be answered were: a) How would an increase of River flow (Q_V) and Nutrient input (N_I) affect trophic state and symptoms of eutrophication (i.e. oxygen stress and HABs), especially along the Canal Oriental? b) Does the frontal zone act as a site for reproduction, nursery and feeding of fisheries resources modified by short- and long-term hydroclimatic variability? and c) How do the consecutive occurrence of hydroclimatic extremes (i.e. the 1998-2000 period), affect the adaptive capacity of the estuarine ecosystems?

The exposed analyzed units were: i) the estuarine frontal zone and ii) the Santa Lucía river lower basin, estuary and associated coastal zone. This project focused on understanding ecosystem response in order to obtain credible estimates of future vulnerability and impacts on: a) trophic status changes (increase in symptoms of eutrophication); b) coastal fisheries and associated livelihood vulnerability; and c) water resources, trophic state changes and sea-level rise in the Santa Lucia river lower basin and estuary. Time horizons considered were from the past 30 years and present through 2030 / 2050 / 2080.

Approach

The overall approach of this multisectoral research has consisted of combining several methods, which can be classified into three main categories: Empirical/Statistical; Global Circulation Models; and Statistical and dynamical downscaling experiments. Statistical and dynamical techniques for downscaling were selected to generate precipitation and temperature daily time series based on future climate change scenarios from the GCMs to bridge the spatial and temporal resolution gaps between climate models and vulnerability assessments requirements. For the statistical downscaling technique the SDSM model (Wilby et al, 2001) was used and PRECIS (Hadley Center's regional climate modeling system) was used to generate future high resolution scenarios over Southeastern South America.

The overall framework of this research is the second generation assessment presented in Figure 6.4 below (Leary and Beresford, 2006).

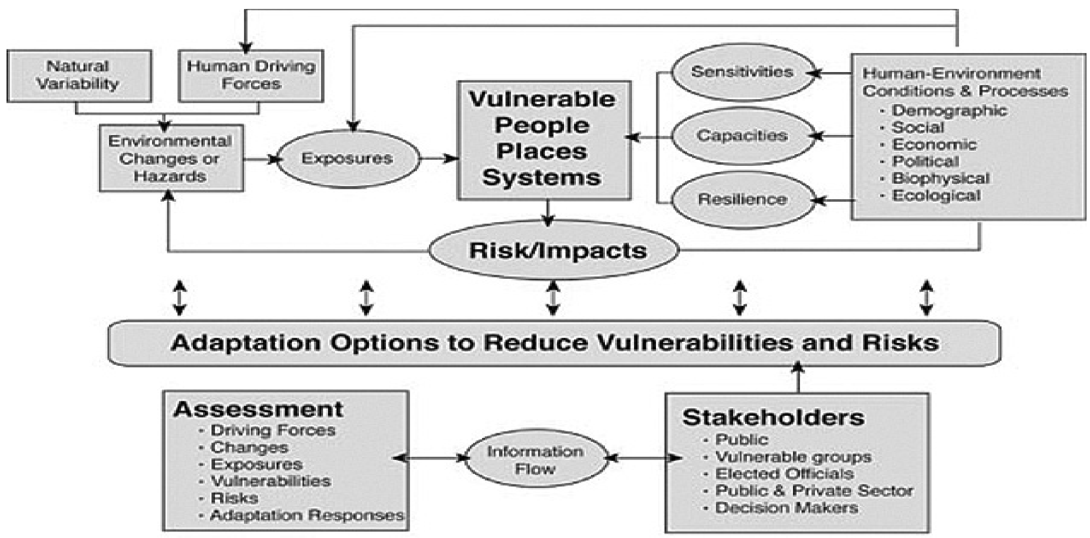


Figure 6.4: Vulnerability, Adaptation and Responses: Assessments (from Leary and Beresford, 2006).

Scientific findings and questions

Climate, hydrologic and oceanographic yearly long-term trends were updated up to the year 2000 / 2003 (temperature, precipitation, sea level pressure, river flows, sea level rise, salinity). The main climatic changes in the Rio de la Plata basin are the increase in ENSO variability and precipitation (≥ 20 percent), southward displacement of the Atlantic subtropical high pressure circulation and changes in frequencies of the prevailing winds; increase in air and water temperatures (≥ 0.8 ºC), as well as changes in runoff, soil moisture and the Pantanal's extent (Díaz et al, 1998; Camilloni and Barros, 2000; Escobar et al, 2004; Bidegain et al, 2005; Liebmann et al, 2004).

Coastal Fishery System

<u>Goal:</u> To assess overall vulnerability of the Coastal Fishery System in the Estuarine Front of the Rio de la Plata to cope with Global Environmental Change.

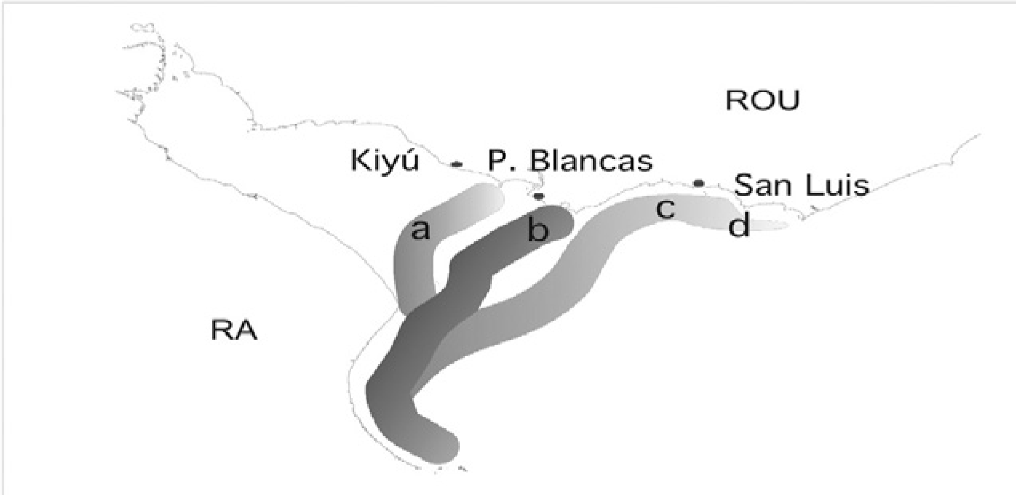


Figure 6.5: Estuarine Front location under different ENSO conditions: a) Strong La Niña event (1999-2000), b) Typical c) Moderate El Niño (winter 1987) d) strong El Niño 1997-1998 / 2002 – 2003; c + d: estuarine plume (modified from Nagy et al., 2002b).

Problem: An artisanal fleet exploits fisheries a few miles off the Uruguayan coast in the estuarine front of the Rio de la Plata. Both, the observations and the economic scenario suggest that in case of an increase in climatic constraints only the better adapted fishermen will be able to remain within the frontal zone fishing area.

Trophic State and Eutrophication: Even if nutrient inputs to the Rio de la Plata are well below the figures for developed countries, they are higher than they were by 1950. In the Rio de la Plata system eutrophication could be considered as a syndrome (a suite of symptoms) that changes with the seasons, years and decades, showing an increasing trend of pressure and state indicators since the mid 1940s, and a shift during the 1970s and 1980s. Driving factors include increases in hydroclimatic means and extremes that lead to an increase in soil erosion and diffuse sources of nutrients. These processes, combined with human activities such as damming have influenced the increase in nutrient load over the last five decades and have altered the natural trophic status and/or stimulated the development of new symptoms, whose drivers are expected to increase (since 1990) in the next few decades (López and Nagy 2005).

Sea Level Rise and coastal vulnerability of the Western Coast of Montevideo: The western coastline of Montevideo (~80 km) is considered to be one of the most vulnerable in the country to sea level rise (Saizar, 1997; Nagy et al, 2005). The only long-term tide-gauge record in Uruguay is located within this coastal section (Punta Lobos). This study used a quantitative index of vulnerability to objectively classify this coastal section as highly vulnerable.

Santa Lucia River Estuary and Coastal Zone: Interannual variability of Santa Lucia river flow (Q_{SL}) is observed to be strongly ENSO-related in the middle basin from August to February although previous studies have indicated a weak ENSO signal in Southern Uruguay (Bidegain and Caffera, 1989). River hydrology, which is partially ENSO controlled, exerts a strong physical control on biogeochemical processes and trophic state changes. Fluctuations in river flow thus induce environmental changes within the system and in the adjacent coastal waters of the estuarine front of the Rio de la Plata.

Future Climate Scenarios and environmental vulnerability: Seven available runs from IPCC Distribution Data Center were selected, using socioeconomic SRES-A2 and B2 forcing scenarios and projected climate fields were compared with observed fields to estimate the regional performance of control simulations (1961 – 1990 baseline). Only four models (HADCM3, CSIRO-mk2, ECHAM4, GFDL-R30) showed an acceptable agreement with the observed monthly and annual Sea Level Pressure field; all scenarios underestimated precipitation; and models have an acceptable agreement with monthly and annual temperature fields. Future climate change scenarios, for precipitation and temperature were constructed for 2020, 2050 and 2080.

Statistical and dynamic downscaling experiments:
Statistical and dynamic techniques for downscaling were selected to generate precipitation and temperature daily time series based on future climate change scenarios from the GCMs to bridge the spatial and temporal resolution gaps between climate models and vulnerability assessments requirements. For the statistical downscaling technique the SDSM model (Wilby et al, 2001) was used and PRECIS (Hadley Center's regional climate modeling system) was used to generate future high resolution scenarios over Southeastern South America.

Some conjectures about plausible climatic and environmental scenarios: Current environmental scenarios (1971-2003) in the Rio de la Plata basin and estuary discussed in this report are dominated by the following main stresses:

- Increases in temperature, precipitation, river flows, sea-level rise and onshore winds.
- Increases in population, damming, use of natural resources and export of nutrients.
- Increases in economic activities, land use changes, soil erosion and runoff / infiltration ratio.

Current climate and future scenarios (time horizon 2020 - 2050) for the Rio de la Plata basin and estuary suggest a change in precipitation, temperature and sea-level rise in the ranges +5 percent to +20 percent, +1 to +2°C and 10-15 cm respectively, whereas during the last few decades these changes have being + 20 to 25 percent for precipitation, +0.5 to +0.8°C for temperature, 5 cm for sea-level rise, as well as + 25 to 40 percent for river flows (Q_V). Trends for Q_V are difficult to estimate due to uncertainty caused by underestimation of precipitation and relative amounts of potential and actual future evapotranspiration rates. If Q_V increases in the range of about 10-25 percent, along with projected temperature increases and economic growth, estuarine and coastal systems could experience significant impacts. Modifications in seasonal circulation and mixing state or stability could be a future possibility and could inducing further environmental shifts and changes resulting in an increase in the degree and occurrence of hypoxic events and in the increasing vulnerability of fishermen and low-lying areas.

Capacity building outcomes and remaining needs

Capacity building

- Project team members have developed Earth System Science and Global Change lectures for a course devoted to High School teachers of Earth and Space Sciences.
- Project team members attended about ten workshops and courses devoted to climate scenarios, climate modeling, vulnerablity and adaptation assessment methods, GIS and Environmental Monitoring, Estuarine Systems, Remote Sensing, Global Enviromental Change and Participatroy Processes.
- Project investigators, G. J. Nagy, A. Ponce and G. Sención attended the AIACC Workshop on Vulnerability and Adaptation in Trieste, Italy (2002).
- Project team members developed lectures on Global Change for a Graduate International course (UdelaR-AEO-Scripps) on Ocean Color for Latin American students.
- Project team members updated the course on Earth System Science and Global Environmental Change for the Master of Science in Environmental Sciences, Facultad de Ciencias, UdelaR.
- Project team members were invited by DINAMA (Uruguay) to present the results of this study in June 2005.

Remaining needs

1. To improve capacities in: a) Vulnerability mapping; b) Integrated climatic, environmental and socioeconomic analysis; c) Quantitative multicriteria assessments of stakeholders perception; and d) Particpatory processes and stakeholders engagement

2. To develop an updated socioeconomic national scenario including all sectors involved in this research. It is expected that this task will be conducted during the Third National Communication (TNC).

National communications, science-policy linkages and stakeholder engagement

Project team members participated in / were engaged in or will participate in the following:

- The revision of the Second National Communication (SNC) Draft under the UNFCCC.
- Several workshops (2003-2005) organized by the Ministry of the Environment: Synergies of the three conventions: Biodiversity, Climate Change and Desertification.
- G. J. Nagy was nomitated by the IPCC to act as a Lead Author of Chapter 13 (Working Group II, Latin America – coasts).
- A series of 4 Prospective workshops organized by the Minisitry of the Environment: "Reflections on Uruguay 2025" (Coastal Zone Working Group).
- A stakeholders meeting organized by another AIACC project (LA26) in Buenos Aires (July, 2004).
- Preparation of the draft on coastal systems vulnerability and adaptation (for the Unit of Climate Change of the Ministry of the Environment i.e. UCC-ME, in order to plan the TNC.
- Project team members were engaged by the UCC-ME to update climate and environmental time-series for the main watersheds and coastal zone of Uruguay and develop high resolution climate models (PRECIS). This information will inform the TNC under the UNFCCC.
- A meeting with the GEF consultant (*Pascal Girot*) who evaluated the capacity to undertake vulnerability and adaptation assessments and climate modeling for the coastal systems and fresh and estuarine waters during the TNC.

Policy implications and future directions

Participation or engagement of the project team members in the following activities has influenced present and future policy on climate change vulnerability and adaptation:

- Cooperating with the Directorates for Water Resources (Ministry of Public Works) and Hydrography and Oceanography (Ministry of Defense), the Public system of education (elementary, high and technical schools) and an agreement with the Russian Academy of Sciences' Institute of Oceanology.
- The Peruvian Report on Vulnerability to Climate Change, CONAMA-Perú, 2005.
- A pre- and full proposal on *Global Change and Sustainable Livelihood in the Rio de la Plata Basin (IAI-CRN II call*). If approved, this project will be the core of future development of global change and sustainability research during the period 2006 – 2010.
- A presentation on current and future climatic and environmental scenarios for the Uruguay river basin and stream (Bi-national Uruguay River Management Committee: Argentina - Uruguay). If future cooperation is agreed upon, vulnerability assessments and adaptation policies to cope with global environmental changes would be planned.
- A presentation on current and future climatic and environmental scenarios and impacts for the Rio de la Plata Basin and estuary to NGOs, journalists and congressmen.

6.6 References

Alvarado, L.F., Campos, M., Zárate, E., Ramírez, P., Bonilla, A. 2005. Escenarios de Cambio Climático para Centroamérica. . CRRH-UCR-CIGEFI-AIACC-LA06). San José, Costa Rica.

Bidegain M, F Blixen, RM Caffera, EA Forbes, JJ Lagomarsino, GJ Nagy, V Pshennikov 2005. Tendencias Climáticas, Hidrolgógicas y Oceanogrráficas en el Río de la Plata y Costa Uruguaya. In :El Cambio Climático en el Río de la Plata (Eds. Barros V, A Menéndez, GJ Nagy), 3:14:137-143, CIMA-UBA, BsAs, Argentina, 200 pp.

Bidegain M. and M Caffera 1989. Anomalías de la precipitación en la Región Sureste de de América del Sur (Uruguay), asociados con el fenómeno El Niño-Oscilación Sur. Poster session, III International Conference on Meteorology of Southern Hemisphere, Buenos Aires, Argentina.

Brklachich, M., D. McNabb, et al. 1997. Adaptability of agriculture systems to global climate change: a Renfrew County, Ontario, Canada Pilot Study. Agricultural restructuring and sustainability: a geographical perspective. B. Ilbery, Q. Chiotti and T. Rickard. Oxon and New York, CAB International: 185-200.

Camilloni I, V Barros 2000. The Paraná river response to El Niño 1982-83 and 1997-1998 events. J. Hydromet., 1:412-430.

Campos, M., Ortiz, B. 2006. Base de datos de noticias sobre eventos extremos 1950-2005. CRRH-UCR-CIGEFI-AIACC-LA06. San José, Costa Rica.

Castro, T., C. Conde, A. Monterroso, G. Rosales. Los Servicios Ambientales De La Subregión Central Del Estado De Veracruz Ante El Cambio Y La Variabilidad Climáticos. Posibles Propuestas De Adaptación. Proyect supported by UNAM.

Conde, C., R. Ferrer, C. Gay, V. Magaña, J.L: Pérez, T. Morales, S. Orozco. 1999. "El Niño y la Agricultura". In: Los Impactos de El Niño en México. Víctor Magaña. México (editor). 103 - 135.

Conde, C., M. Vinocur, C. Gay, R. Seiler. 2006. Climatic Threat Spaces as a Tool to Assess Current and Future Climatic Risk in Mexico and Argentina. Two Case Studies. Vulnerability to Climate Change in the Developing World. AIACC Working Paper No. 30.
http://www.aiaccproject.org/working_papers/working_papers.html.

Díaz AF, CD Studzinski, CR Mechoso 1998. Relationship between precipitation anomalies in Uruguay and Southern Brazil and sea surface temeprature in the Pacific and Atlantic Oceans. J. Climate, 11:251-271.

Escobar G, W Vargas, S Bischoff 2004. Wind Tides in the Rio de la Plata Estuary: Meteorological Conditions. Int. J. Climatol. 24:1159-1169.

Gay, C., F., Estrada, C. Conde, H. Eakin, L. Villers. 2006. Potential impacts of climate change on agriculture: A case of study of coffee production in Veracruz, Mexico. Climate Change (in press).

Hulme, M., Wigley, T.M.L., Barrow, E.M., Raper, S.C.B., Centella, A., Smith, S.J. and Chipanshi, A.C., 2000: *Using a Climate Scenario Generator for Vulnerability and Adaptation Assessments: MAGICC and SCENGEN Version 2.4 Workbook*. Climatic Research Unit, Norwich UK, 52 pp.

Intergovernmental Panel on Global Change (IPCC) 2001. IPCC WGI Third Assesment Report: The Scientific Basis, Chapter 2. *Cambridge University Press.*

Intergovernmental Panel on Climate Change (IPCC). 2001b. Summary for Policy Makers. A Report of Working Group I of the Intergovernmental Panel of Climate Change. Cambridge University Press. 20 pp.

La Red. Social Studies Network for Disaster Prevention in Latin America.
Available: http://www.desinventar.org/desinventar.html

Liebmann B, C Vera, L Carvalho, I Camilloni, M Hoerling, D Allured, M Bidegain, J Baez, V Barros 2004. An observed trend in Central South American precipitation. J. Climate)in press)

López CH, GJ Nagy 2005. Cambio Global, Evolución del Estado Trófico y Floraciones de Cianobacterias en el Río de la Plata. In :El Cambio Climático en el Río de la Plata (Eds. Barros V, A Menéndez, GJ Nagy), 3:16:157-166. CIMA-UBA, BsAs, Argentina, 200 pp.

Magaña, V. (editor). 1999. Los Impactos de El Niño en México .México. UNAM, IAI; SG. 228 pp. http://ccaunam.atmosfcu.unam.mx/cambio/nino.htm.

Magaña V., J. Amandor y S. Medina, 1999. The mid-summer drought over Mexico and Central America. *Journal of Climate*, 12, 1577-1588.

Magaña V., J. Vázquez, J. Perez y J. Perez, 2003. Impact of El Niño in México. *Geof. Int*., 42(3), 313-330.

Masera, O., López-Ridaura (eds). 2000. Sustentabilidad y Sistemas Campesinos. Cinco Experiencias de Evaluación en el México Rural. México. D.F.

McCarthy, J., O. Canziani, N. Leary, D. Dokken, and K. White (eds). 2001. *Climate Change 2001: Impacts, Adaptation and Vulnerability.* Contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, UK and New York, USA.

Nagy GJ, Martínez CM, Caffera M, Pedrosa G, Forbes E, Perdomo AC, López Laborde J. 1997. The Hydrological and Climatic setting of the Río de la Plata. Chapter 2 In Wells, P.G. & G.R. Daborn (Eds), The Río de la Plata. An Environmental Overview. An EcoPlata Project Background Report. Dalhousie Univ, Halifax, Nova Scotia, 248 pp.

Nagy GJ, M Bidegain, M Caffera, C López, A Ponce, G Sención 2002c Evaluación de la vulnerabilidad ambiental al cambio global. Perfil Ambiental del Uruguay / 2002: 15-25. A Domínguez, RG Prieto (eds), Ed. Nordan Comunidad, Montevideo.

Nagy G J 2000. Dissolved Inorganic NP Budget for the Frontal Zone of the Río de la Plata system. Estuarine Systems of the South American Region: C, N, P Fluxes 2000. LOICZ UNEP workshop reports. Dupra, V., S.V. Smith, J.I. Marshall Crossland & C.J. Crossland (Eds), Loicz Reports and Studies 15, LOICZ, Texel, The Netherlands.

Nagy GJ 2005. Vulnerabilidad de las Aguas del Río de la Plata: Cambio de Estado Trófico y Factores Físicos. In :El Cambio Climático en el Río de la Plata (Eds. Barros V, A Menéndez, GJ Nagy), 3:15:145-155, CIMA-UBA, BsAs, Argentina, 200 pp.

O'Brian, K.L., R.M. Leichenko. 2000. Double Exposure: assessing the impacts of climate change within the context of economic globalization. Global Environ. Change. Elsevier Science. 10: 221- 232.

Sánchez, G., M.A. Medina, C. Conde. 2005b. Submitted to CONACY – SEMARNAT.

Scoones, I. 1998. Sustainable Rural Livelihoods: A Framework for Analysis. IDS Working Paper.

Wilby, R.L., Dawson C.W., and Barrow, E.M. 2001. SDSM – a decision support tool for the assessment of egional climate change impacts. Memeo, February 16, 2001 (under review)

Ziervogel, G., A. Nyong, B. Osman, C. Conde, S. Cortés and T. Downing. 2005. Climate Variability and Change Implications for Household Food Security. Vulnerability to Climate Change in the Developing World. (accepted)

7 Climate change assessments in Small Island States

Three projects addressed diverse issues related to impacts of climate change and adaptation strategies for the small island states. The study in the Caribbean countries focused on issues of human health, particularly on the threat of dengue fever. A project on climate change impact modeling was undertaken for Fiji and the Cook Islands and the third study dealt with the impacts of climate change on the tourism industry in Seychelles and the Comoros. A brief description of the findings of each case study is provided in the form of short summaries below.

* Details about the scientific literature referenced in the project summaries below are available in the final project reports accessible at: http://www.aiaccproject.org/Final Reports/final_reports.html

7.1 The Threat of Dengue Fever in the Caribbean: Impacts and Adaptation (SIS06)

Summary Information

Country: Jamaica, St. Kitts & Nevis, Trinidad & Tobago, and other members of the Caribbean Epidemiology Centre (CAREC)
Principal Investigator: Prof. A. Anthony Chen
Administering Institution: The University of the West Indies, Kingston, Jamaica.

Research Problem

The Intergovernmental Panel on Climate Change (IPCC) in 1998, using a WHO source, indicated a likely alteration of the global distribution of dengue - a mosquito vector borne disease - due to climate change, with 2.5 billion people at risk in the tropics and subtropics. In the Caribbean, since the last decade, there has been a significant increase in dengue cases with increasing severity of dengue haemorrhagic fever occurrences and the concurrent local circulation of all four dengue virus serotypes, as illustrated in Figure 7.1.

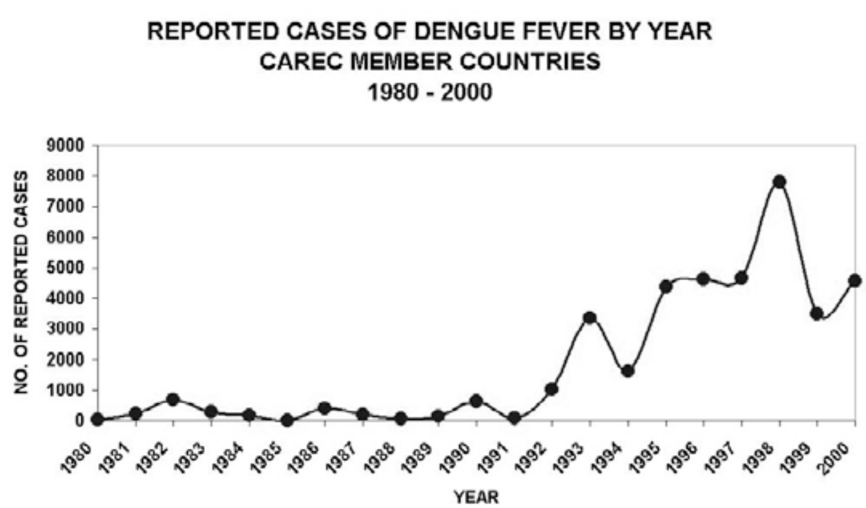


Figure 7.1: Number of reported cases of dengue fever in CAREC countries from 1980 - 2000

Dengue haemorrhagic fever (DHF) and dengue shock syndrome (DSS) have been shown to be the most vicious form of the disease in the Americas. Dengue outbreaks have impacted all sectors of the society including manufacturing, commerce and the tourism industry on which the region so heavily depends. In 1995, tourism accounted for 69 percent and 53 percent of the GNP in Antigua and the Bahamas respectively, and more than 10 percent in most other islands in the Caribbean (IPCC, 1998). The loss of productive time and the cost of treating the illness also make dengue epidemics a major cause of concern.

It is widely accepted that dengue epidemics result from a combination of factors including social, biological and environmental factors, such as social inequalities, poor sanitation and an abundance of stagnant water sources such as discarded automobile tires and other non-biodegradable containers. Climatic factors have also been implicated and research suggests that the transmission rate of dengue fever could increase with temperature (Hales et al, 1999) largely due to the shorter incubation periods required (Focks et al, 1995 and Koopman et al, 1991). Research has also shown an association of increased dengue transmission with climatic variability associated with the El Niño Southern Oscillation (ENSO) phenomenon (Hales et al, 1996). Warmer temperatures in combination with abundant breeding sites in the form of stagnant water in pools on the ground or in cans / tanks / discarded containers are likely to result in dengue upsurges in the El Niño and the El Niño +1 years (Poveda et al, 2000 and Chen and Taylor, 2002). Peaks in the incidence of dengue in the Caribbean in the El Niño years 1982 and 1986, the El Niño + 1 year 1992 extending into 1993, and in the El Niño + 1 year of 1998 can be observed in Figure 7.1. Projected temperature increases of about 2ºC resulting from a doubling of atmospheric CO_2 and no change in precipitation (Santer, 2001) coupled with known El Niño induced temperature increases, could result in increased vector abundance and dengue fever incidences and pose a serious threat to the Caribbean. Adaptation strategies to counteract this threat would therefore have to be developed.

Overall aim

The overall aim of this project therefore was to establish the relationship between the incidence of dengue and climate, and to lay a framework for developing adaptation strategies, keeping in mind that the ability to predict climate, especially the onset of El Niño, is constantly improving.

Primary objectives

The primary objectives of this project were:

1. To determine the extent of the association between climate and the incidence of dengue across the Caribbean region and the dominance of this linkage in comparison to other linkages.
2. To identify and evaluate adaptive options to ameliorate the impact of climate on dengue.
3. To use research findings to determine future impacts and adaptation based on global change scenarios of the future.
4. To make the knowledge gained accessible and useful to decision-makers.

Approach

The approach to assess impact of and vulnerability and adaptation to climate change and to disseminate knowledge involved nine main tasks:

1. Development of climate and epidemiology databases
2. Analyzing the relationship between climate and epidemiological patterns of dengue fever and its vector in (i) a retrospective study and (ii) a prospective study.
3. Obtaining downscaled future projections of climate for the Caribbean from coupled atmosphere ocean general circulation model (AOGCM) outputs using the Special Report on Emissions Scenarios (SRES) of the Intergovernmental Panel on Climate Change (IPCC).
4. Executing a socio-economic study to determine the vulnerability of a typical community to dengue fever.
5. Conducting a Knowledge, Attitude and Practices (KAP) survey to determine the level of understanding of climate change and public health issues relating to dengue fever, and to ascertain willingness to undertake adaptation strategies for dengue fever prevention.

6. Designing a pilot project for Jamaica to implement an integrated system capable of monitoring vector and disease, forecasting climate and dengue incidence, and undertaking diagnostics and adaptation applications for the near term (5 years or less).
7. Determining the type of containers that provide the most effective reproduction grounds for the disease vector (mosquitoes) in order to target them in any vector eradication program.
8. Analyzing adaptation strategies for dengue using climate projections, socio-economic information and knowledge gathered from the study.
9. Engaging stakeholders by conducting workshops and disseminating reports.

Scientific findings

The climate and epidemiology databases were successfully developed, despite problems with obtaining climate data and with the quality and reporting of epidemiology data. A retrospective study was conducted to determine: the nature and extent of the association between climate and the incidence of dengue across the Caribbean; to quantify the association in terms of a measurable parameter such as temperature; and develop a procedure to predict the potential for the onset of dengue. The results revealed an association of the disease with climate, especially via temperature and via El Niño episodes (El Niño and El Niño+1 events). This association was more pronounced in the Trinidad and Tobago data. Indices linked to temperature (early temperature peak, lapse time to disease onset, average temperature at disease onset, and the Moving Average of the Temperature (MAT) – roughly the average temperature to date from the start of the year) helped to predict the potential for the onset of dengue. A prospective study was also carried out to determine the relationship between climate, the dengue vector and disease in selected Caribbean countries i.e., Trinidad and Tobago, Jamaica, Barbados, St. Kitts and Nevis and St Vincent and the Grenadines. Study results confirmed the presence of "a dengue season" in Trinidad, coinciding with the rainy season, and established that temperature alone did not appear to be associated with an increase in dengue occurrence. Thus while temperature can be used to determine the potential for the onset of dengue, it cannot by itself predict an occurrence. The Breteau index, the total number of Aedes aegypti (i.e. the dengue vector) positive containers detected per 100 homes inspected was found to be a good indicator for the potential of disease occurrence in a dengue endemic environment.

Because of economic constraints the socio-economic analysis was conducted only for the island of Jamaica, which is a good representative of the situation on the other islands. A mixed methodology was adopted, consisting of expert interviews and a questionnaire survey, backed by secondary data, to assess the capacity of the country to respond to any crisis including outbreaks of dengue fever (specific adaptive capacity). The results revealed that a lack of any real economic growth since the 1970's has affected Jamaica's ability to respond to any crisis including a dengue epidemic. Interviews with experts from the Ministry of Health revealed that resource problems limit the ability of the organization to conduct routine vector surveillance and implement control programs and public education programs. The study also revealed that the poor were most vulnerable to dengue fever, largely because they lived in informal settlements where conditions are conducive to the proliferation of the dengue vector and virus. Many of these poor households were headed by females, most of who were unemployed, had no skills and displayed a high level of ignorance regarding the disease and its transmission.

Knowledge, Attitude and Practices (KAP) surveys, to determine the level of understanding about climate change and public health and attitudes towards adopting adaptation strategies, were carried out in Trinidad and Tobago, Jamaica and St. Kitts and Nevis. The study concluded that despite the fact that knowledge and attitudes did not always coincide with practices of using environmental sanitation for dengue fever prevention, it seemed that respondents could be persuaded to use such strategies. There was also a need for promoting community involvement, and for demonstrating the efficacy of using climate change information in dengue fever, and possibly other disease, prevention.

The pupae survey project revealed that 40 gallon drums commonly used for outside water storage in the Caribbean are the main mosquito breeding grounds.

To generate the future climate expected in Caribbean, outputs from coupled Atmospheric Ocean Global Climate models (AOGCM) based on A1 and B2 SRES emission scenarios were downscaled statistically.

Time slices for the 2020's, 2050's and 2080's were processed by Canadian Climate Impacts Scenarios (www.cics.uvic.ca/scenarios/index.cgi?Scenarios) for use in the statistical downscaling model, SDSM, developed by Wilby et al (2002). The results indicate a likely temperature increase of about 2ºC by 2080's, which could lead to a 3-fold increase in the transmission of dengue fever (Focks et al, 1995 and Koopman et al, 1991). The results for precipitation on the other hand were very uncertain and more investigation is needed, especially with the use of regional climate models.

Strategies for adaptation were developed based on the above results keeping in mind that there exists an adaptation deficit in addressing the prevention of dengue. These were developed by means of (i) identification and classification of current adaptive strategies through collaboration with Health Ministries, (ii) use of a matrix analysis to examine the characteristics and constraints of present adaptive practices and possible future practices, and (iii) the identification via expert judgment of a limited best set of practices, for recommendation to government officials and other stakeholders. An early warning system to predict the potential for the onset of dengue was one of the adaptation strategies developed. It relies mainly on the rate of increase of the MAT index, with a greater rate of increase indicating early potential for dengue. This system is cost effective because costly surveillance for the disease need only be implemented when the MAT index approaches threshold value.

Capacity building outcomes and remaining needs

Five staff members of The University of the West Indies, Mona, Jamaica and St. Augustine, two from the PAHO/WHO Caribbean Epidemiology Centre, Trinidad, and several from the Ministries of Health, Jamaica and Trinidad and Tobago were involved in the project. As a result of the project, researchers at these institutions have learnt interdisciplinary techniques of studying climate change impacts on dengue occurrence and developing adaptation strategies using both climate and epidemiology data. The project has also helped establish a collaborative research association between institutions and this is likely to continue in future. Collaboration will be especially important when new climate change scenarios become available and new disease associations and trends emerge.

In addition, a major component of the project was the training of 7 graduate students. A pressing need is now to ensure that these students can find appropriate employment where their acquired skills in the area of climate change can be used directly or indirectly in governmental, environmental, educational and/or research institutions.

National communications, science-policy linkages and stakeholder engagement

The results of this project will definitely be included in Jamaica's National Communication, and efforts are being made to have it included in the Communications of other islands. This project has laid the foundation for providing the basic inputs for decision making and it is assumed that collaborative research on climate change will continue even after the project's conclusion, so that there will always exist a body of researchers who can be called upon to provide the necessary input to decision making. These researchers can provide the expertise in determining the level of reliability or uncertainty of climate change projections, the severity and spatial extent of the threat, the adaptation strategies to be employed and the projected outcome. Decisions makers must consider all these inputs among others like economic considerations, in arriving at decisions on adaptation strategies.

To hasten the process and to explain the project's relevance to decision makers, two workshops were held in Trinidad and Jamaica at the end of the project to outline the results and their potential for influencing decision making. The results were well received at both workshops, and the Director of the Disease Prevention and Control Division of the Ministry of Health in Jamaica has indicated that she would like to set up a simple form of the proposed early warning system, and further discussions are to be arranged.

Further, the results of the project are to be disseminated among all stakeholders in the form of (i) CD's of the workshop presentations and (ii) a monograph of the results of the project which can be used for classroom and workshop purposes.

Policy implications and future directions

The project has demonstrated a linkage between climate and dengue occurrence and has made recommendations for adaptive strategies, including an early warning system. It is for the main stakeholders, the Ministries of Health in the region, to evaluate and, if necessary, implement these recommendations. In the meanwhile, there is need for the research community to investigate the impact of climate on other diseases such as respiratory diseases (e.g. asthma), as well as food- and water-borne diseases.

7.2 Modeling Climate Change Impacts on Viti Levu (Fiji) and Aitutaki (Cook Islands) (SIS09)

Summary Information

Country: Fiji and Cook Islands
Principal Investigator: Kanayathu Koshy
Administering Institution: PACE-SD, University of South Pacific, Suva, Fiji

Research problem

An important activity of the Pacific Islands Climate Change Assistance Program (PICCAP), an enabling activity funded by the Global Environment Fund (GEF), was the development of integrated assessment models to support Vulnerability and Adaptation (V&A) assessments and capacity building in Pacific island states. This interdisciplinary work uniquely linked climate change data, models, and projections with sets of sectoral impact models at the island scale, for both temporal and spatial analyses. The first model developed under this activity was VANDACLIM – The Islands Version (for a fictitious country; Warrick et al, 1999), a software tool in support of training in V&A assessment. The generic developments for VANDACLIM fueled the development of a set of prototype integrated assessment models for real places in the Pacific, like Rarotonga (Cook Islands), Viti Levu (Fiji) and Tawara (Kiribati). These "first-order" models contain a climate change scenario generator, island-specific climate data, and a mix of agricultural, coastal, water and health models for impact analyses. These user friendly models serve as evolving platforms for integrating scientific knowledge and data to inform policy and planning in the context of climate change and variability. Recent advances in integrated assessment methods, including a recent World Bank supported V&A study focusing on Fiji and Kiribati (World Bank, 2000) provided support for further development of these models, especially for Fiji.

The major limitation of these "first order" integrated assessment models was that they could only address the sectoral bio-physical impacts of climate change. The human dimension (population, infrastructure, and land use) was not considered although it has implications on the capacity of sectors to cope with climate risks and the range of adaptation options that can be considered. This provided and opportunity for the SIS09 research team to combine the bio-physical impacts with the human dimension (see Figure 7.2) and develop the "next generation model" for integrated assessment (SimCLIM) based on recent advances in socio-economic baseline changes, infrastructure effects, adaptation, and community-level coastal impacts and economic valuation.

The summarized research objectives of the project were as follows:

1. To provide the "next generation" integrated assessment model.
2. To implement, test and apply improved methods for integrated assessment.
3. To build a sustainable, in-region capacity to conduct research and integrated assessments.

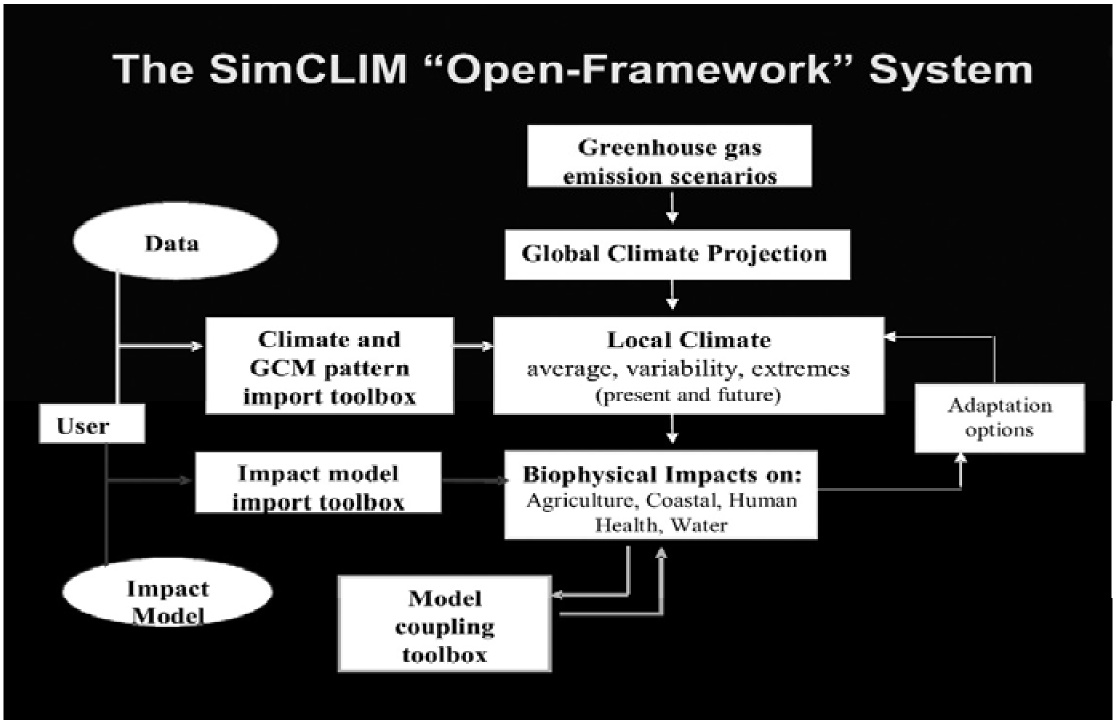


Figure 7.2: SimCLIM "Open-Framework" system (adapted from Warrick et al, 2005)

Approach

The approach was largely guided by the research objectives with some variations to account for the paucity of data and revisions to the SimCLIM open framework. For the first objective, the existing three-tier model structure used in the "first generation" model served as the mechanism for integrating methods, models, data and scenarios (under the second generation model), allowing the user to:

- Describe and examine baseline climates
- Create climate change scenarios
- Evaluate impact models
- Conduct sensitivity analyses
- Estimate sectoral impacts of climate and sea level change
- Examine scientific and modeling uncertainties
-

For objective 2, a case study approach was used for implementing and testing the methods developed in objective 1, and for carrying out integrated assessments of impacts and adaptation that provided new understanding about the effects of climate and sea level changes in the Pacific region. The two case study sites were:

- Navua and Natadola in Viti Levu (Fiji): Viti Levu is a high mountainous island with highly populated coastal zones and is subject to numerous land use changes. The project focused on the effects of climate and sea level changes and variability on the coastal zone, flood plains and infrastructure and examined opportunities for adaptive response.
- Aitutaki in the Cook Islands: Aitutaki is a typical low-lying atoll island in the Pacific. In terms of the impacts of climate change on this island, rainwater was identified as a key resource constraint. We therefore focused on rainwater harvesting, and the implications of climate change and variability on its sustainability.

- For objective 3, several approaches were used, including field surveys, targeted training workshops and sites visits for the training of government and non-government officials, University of South Pacific (USP) staff and students, and high school students (in Aitutaki). Secondly, young professionals from the region were introduced to the training version of SimCLIM (TrainClim) through a "hand-on" training approach in preparation for using TrainClim in the USP-based climate change vulnerability and adaptation assessment course. Finally workshops, scientific publications and other public forums were used to raise awareness about climate change and the project and its outputs. The lessons learnt from this project will be shared with other such projects in the Pacific to sustain regional capacity to conduct integrated assessments on climate change.

Scientific findings

The most significant achievements of this project can be summarized as follows:

1. The "next generation" integrated model suitable for impact and adaptation assessment in small island states has been developed with the following capabilities:

    - *Capacity for sub-island (community-scale) assessments:* A nested, multi-scale capacity was developed within the single integrated system to determine impacts and adaptation at different scales and to "scale up" from local to national levels. This has increased the potential scope of case study applications and the flexibility for addressing a range of impact and adaptation issues.
    - *Components for the "human dimensions" (e.g. population, infrastructure, land use) of vulnerability*: Model components to allow the incorporation of spatially related demographic, land use and infrastructural data were developed, including the graphical and tabular tools for displaying such data in a three-dimensional capacity.
    - *A socioeconomic scenario generator to project changes in baseline conditions*: This activity has focused specifically on the provision of a land use scenario, particularly with regard to buildings at risk from river and coastal flooding. It allows the user to develop growth patterns of settlements based on assumptions about trends in population growth, building types and mix, and land constraints.
    - *Develop capacity for generating island-specific sea-level rise scenarios*: The integrated model system was modified to allow the incorporation of local relative sea-level trends, regional sea-level change patterns, and global-mean projections. This was also used to examine changes in extreme events (e.g. storm surges) and their return periods and to examine flooding impacts and adaptations by linking with an extreme event analyzer and coastal flooding impact model respectively.
    - *Developing coastal impact models appropriate for coral and coral-fringed islands:* We emphasized upon impact models relevant to both riverine and coastal flooding, at a scale appropriate for examining community-level impacts. The basic approach is complete and efforts are on to make the models "generic" and easily applicable to different settings.
    - *Develop an explicit adaptation component:* Modeling capacity has been developed to explicitly examine adaptation options to address flood risks. Adaptation options are broadly related to "flood proofing" of structures, engineering works and land use regulation.
    - *Modify and incorporate economic tools for both valuation of impacts and evaluation of adaptation measures:* Simple and straightforward methods were developed that could be applied generically across a range of cultural and economic situations found within the Pacific islands. Basic tools for benefit-cost analyses were also developed to evaluate the economic viability of adaptation measures. The integrated model can simulate economic impacts over time and also allows for the separation of benefits and costs of adaptation under climate change from those occurring under natural climate variability.
    - *The capacity to allow models to run in "transient" mode*: In contrast to the "time slice" comparisons (e.g. 1990 *versus* 2050) of the first generation models, this model can capture the effects of climate variability and extremes along with a *changing* climate and/or sea level over time. Importantly, this enables the characterization of costs of

impacts (and benefits of adaptation) as "streams" or "flows" of effects into the future, which are then discounted back to the present to evaluate the incremental cost of adaptation options.

2. It was determined that climate change adaptation must connect top-down and bottom-up approaches underpinned by lessons learnt from experiences with climate variability and extreme weather events. Moreover, all stakeholders involved in planning, implementing, and monitoring adaptation measures must have clearly defined responsibilities.
3. We also identified that local communities are "locked" into a vulnerable situation because of their poor socioeconomic conditions, their lack of ability to influence government decision-making processes and lack of access to financial resources. Assistance to these communities to adequately adapt to climate change would therefore be important.

Capacity building outcomes and remaining needs

The project implementation in itself proved to be a learning experience for the participants due to the paucity of key relevant data and information, which necessitated variations and adjustments to the implementation approach. Several secondary and tertiary level students were engaged in field work for the project, thus building their capacity to carry out multidisciplinary field assessments where interaction with stakeholders through interviews and observation were followed by analysis of information and data gathered. The field experience gained by these students is an important outcome of this project.

About 40 young pacific professionals working with various government and private agencies were introduced to the SimCLIM model via its training version (TrainClim), through several workshops. The participants appreciated the capacity of the tool to: (i) give pictorial representations of climate change scenarios, (ii) allow the user to use climate change information for simple planning problems, (iii) define and evaluate adaptation options, (iv) perform cost benefit analysis and (v) model coastal inundation, freshwater lens, health impact and shoreline change.

In terms of long term capacity building, TrainClim will be incorporated into the USP-based climate change vulnerability and adaptation assessment training. Relevant stakeholders from Pacific Island Countries need to be trained in the application of SimCLIM, but more importantly to interpret and analyze the outputs from the next generation model. These needs extend beyond the scope of this project however, the platform to meet this need is the planned incorporation of TrainClim into the USP-based training.

National communications, science-policy linkages and stakeholder engagement

This project's direct contribution to the first national communications of the two countries (Cook Islands and Fiji) was minimal because when it began in 2003, Cook Islands had already submitted its National Communication and Fiji had completed its assessments and was finalizing the report. The project outputs will therefore be useful for their second national communications. It must however be recognized that researchers from this project did provide climate change related technical expertise to the first national communication even before the AIACC project started.

Numerous stakeholders were engaged at various stages of the project, including government officials and local communities. The project's official focal points in the Cook Islands and Fiji were the government departments responsible for environmental services. They were engaged in the project formulation and implementation stages especially in providing over sight on national priorities with implications for climate change adaptation in the project sites. Government officials from other Pacific Island Countries were engaged during the project's stakeholder workshops and other climate related meetings and training sessions organized by the project investigators within Fiji and in the region.

Policy implications and future directions

In most Pacific Island Countries, policy formulation and implementation are seldom informed by science. Key development policies pertaining to climate sensitive sectors such as agriculture, water resources, and the coastal zone are often made without scientific scrutiny. For example, Pacific Islands Countries are known to be among the most vulnerable to the impacts of climate change (IPCC, 2001b), however, climate change does not feature as one of the key factors in the design and formulation of development plans (Mataki et al, 2006). Even inter-annual climate variability (El Niño) and extreme weather events (e.g. tropical cyclones, flash floods) are only responded to as and when such events occur; very little effort has been directed towards reducing their impacts with policy modification or development and implementation of robust adaptive measures. The capacity building aspects of this project especially in relation to climate change adaptation planning and the use of scientific data to inform adaptation had contributed to raising the level of awareness among government officials, communities, and academics. More importantly, this project had proven to critics, the significance of modeling in the area of climate change vulnerability and adaptation assessment.

This is important because so far there has been very little scientifically proven data and information to inform policy formulation and action in most Pacific Island Countries. The efforts of practitioners and advocates for climate change adaptation in the Pacific have been questioned and there has been scepticism about the ability of proposed measures in various climate change adaptation projects to address climate change impacts at the sectoral level (water, agriculture coastal zone). Concerns about the validity of measures can be allayed with scientifically proven data and information, and SimCLIM is one such tool that can be used to generate local level vulnerability and adaptation assessment information and data.

In contrast to the top down scenario driven approach used in the past for assessing vulnerability and determining adaptation options to climate change, a more realistic bottom up approach has been popularized by UNDP through their Adaptation Policy Framework, which is a development driven pathway with emphasis on adapting to the present day climate vulnerability. This requires the development of a baseline scenario to which the impact of any development activity or climate change can be added to determine the resulting vulnerability and plan and implement adaptation measures. The advantage is that the adaptation in this case will be transient and not time sliced as with past approaches. The SimCLIM model developed by this project has this ability to implement the bottom up approach and has the capacity to:

- Describe baseline climates
- Examine current climate variability and extremes
- Assess risks – present and future
- Investigate adaptation – present and future
- Create climate change scenarios
- Conduct sensitivity analyses
- Examine sectoral impacts
- Examine risks and uncertainties
- Facilitate integrated impact analyses

7.3 Impact of Climate Change on Tourism in Seychelles and Comoros (SIS90)

Summary Information

Country: Seychelles and Comoros
Principal Investigator: Rolph Antoine Payet
Administering Institution: Department of Environment, Victoria, Mahe, Seychelles

Research problem and objectives

The impact of long-term climate change on tourism still remains unclear. Although several studies have been undertaken on understanding the relationship between climate change and tourism, an approach that considers the linkages between the resource base of tourism and its socio-economic aspects has not been adequately investigated for the small islands. Six tourism sites in Seychelles were therefore examined in terms of their ecological status and support systems, tourism development model, recreational value and management to analyze the impacts of climate change on these attributes. National development scenarios were constructed after scaling up the results to determine which development scenarios are sustainable and which ones provide opportunities for adaptation in the short-to-medium term.

The specific research objectives were:

1. Identify the linkages between various anthropogenic and climate stressors in the context of the coastal marine environment in small islands.
2. Determine the impact of climate change on natural resources and tourism
3. Evaluate various adaptation options and policies in the context of climate change
4. Investigate the effect of early adaptation and management costs under the climate change scenario

Approach

The approach to the research constituted of an analysis of environmental, economic, social and participatory issues in coastal tourism whereby climate change is considered an exogenous factor. This resulted in a number of model results and outputs, which was combined within a multicriteria framework to investigate adaptation options to climate change. The methodological framework is shown in Figure 7.3, followed by a description of the approach taken.

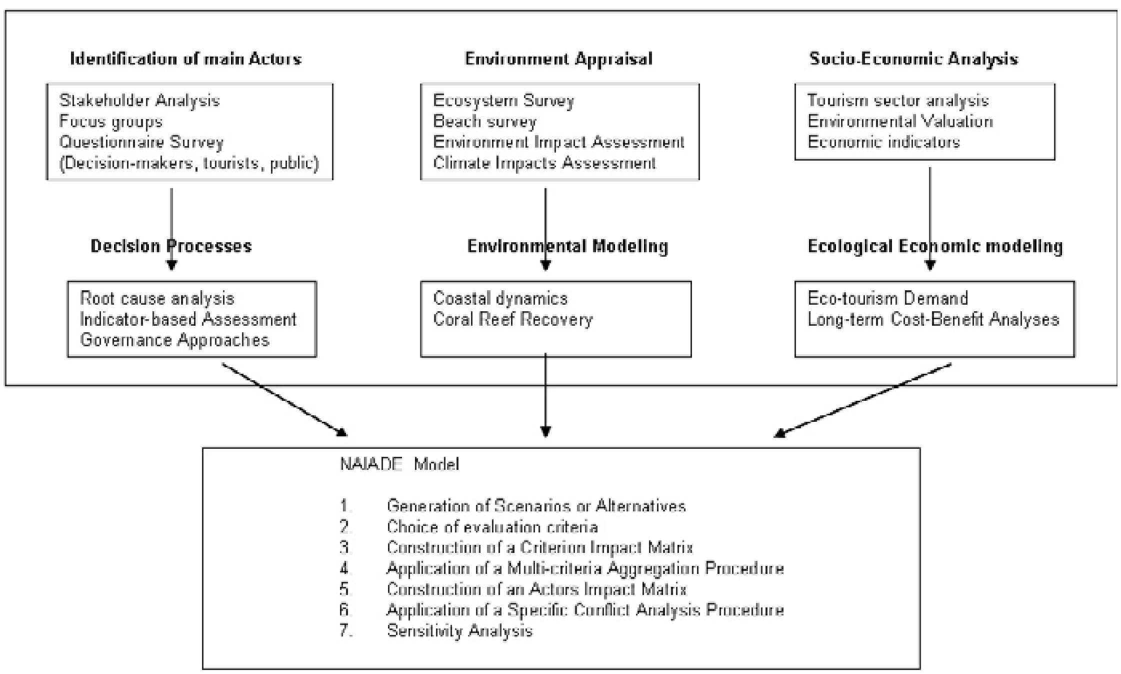


Figure 7.3: Integrated Research framework

Climate Change Scenarios

Climate change scenarios were generated using 30 year historical data from the Seychelles and the MAGICC/SCENGEN scenario generation model for four time slices 2020s, 2050s, 2080s and 2100s Three GCMs, HadCM3, ECHAM4 and CSIRO were used with two greenhouse gas emission scenarios, IS92a and IS92c, and two IPCC Special Report on Emission Scenarios (SRES) storylines – A2 and B2. Temperature, rainfall and sea-level changes were the climate variables studied and runs were based on the Seychelles

1961-1990 baseline climate. Scatter plots of mean temperature change versus precipitation change were calculated to illustrate the distribution of scenario changes for Seychelles on a monthly, seasonal, or annual basis.

Actor determination and decision analysis

The characteristics of actors (including future generations) who are/would be involved and are/would be affected by tourism development was determined. Actor stakes and long-term expectations were determined from focus group discussions and in-depth interviews (Payet, 2003).

The decision analyses involved one-to-one surveys of senior policy-makers in Seychelles, which were then assessed within a Pressure-State-Impact-Response (PSIR) indicator framework (after OECD, 1993). Information on actors such as fishermen and tourists were also obtained from surveys conducted by Wakeford (2000) and Cesar *et al* (2004).

Biophysical assessment

The aim of this assessment is to quantify and analyze the impacts of climate change on critical tourism resources such as coastal land, coral reefs and marine life. An Excel based model was developed to estimate onshore wave energy and its impact on Seychelles beaches (Sheppard *et al*, 2005). Data on ecosystem assessments by Engelhardt (2000 & 2004) was combined with data collected under this study to develop a model to study ecosystem resilience, in terms of recovery from recent coral bleaching and other anthropogenic effects. Time series abundance indices and yields were used to establish trends in fish resource status prior to the 1998 bleaching event and an attempt was made to examine the short term impacts of mass coral mortality on Seychelles reef fisheries using a hierarchical nested analysis of variance model. Spatial analysis was undertaken using ARCINFO/ARCVIEW, coupled with field assessments at 10 beach sites and data collection to determine beach profiles. An evaluation of the contribution of human impacts was also undertaken.

Socio-economic Assessment

The approach is based on several investigations to evaluate the socio-economic impacts of marine degradation in the Seychelles, using both revealed preference methods and expressed preference techniques (Cesar *et al*, 2004). This consisted of (i) an assessment of the economic value of marine ecosystems and resources, their components, and the corresponding economic sectors; (ii) impacts on socio-economic sectors; and (iii) development of 'what if scenarios' for future management. Questionnaire surveys (tourists and residents), information from national accounts, economic analysis based upon the contingent valuation methodology (CVM), information on the economic importance of each affected sector and expenditure costs provided by survey respondents or the national authority were used for this purpose. Cost-benefit analysis was used to evaluate various management and adaptation strategies.

Model for Multi-criteria Analysis

The NAIADE (Novel Approach to Imprecise Assessment and Decision Environments) MCA method developed by Munda (1995) was adopted for this study, as it offered the opportunity to mange the various types of data to address the multidimensionality of tourism. It also allows the analysis of actors and conflicts using an equity module.

Scientific findings

This section highlights the findings of each of the various components of the research project, and finally presents the application of these findings in a multivariate model based upon various development scenarios.

Climate Scenarios

The scenarios generated in this study predict several changes in the climate of Seychelles relative to the 1961–1990 baseline. Maximum and minimum temperatures are expected to increase for all the seasons, ranging from 0.63 to 3.67°C. The dry season in Seychelles will become drier and the wet season wetter. Most models predict an increase in the wet season ranging from -28.20 percent to +22.68 percent. The change in sea surface temperature under the IS92a scenario is expected to range from 0.3°C to 2.5°C. A rise in sea surface temperature by 1°C and a shift to El Nino conditions could expand the cyclone path equatorward. In general an increase in the frequency and severity of extreme events is predicted. The balance of evidence indicates that ENSO events may occur more frequently leading to higher average rainfall over the Seychelles during an intense El Nino and abnormally low rainfall during an intense La Nina.

Reef ecosystems and recovery

The significance of the 1997-1998 coral bleaching event in the Seychelles was the complete coral mortality (50 to 95 percent cover). Monitoring data from this area from 1998 to 2004 shows a positive trend in recovery despite repeated coral bleaching events in 2002 and 2003 (Payet et al, 2005). Such recovery is however not uniform across the archipelago and the granitic reefs were found to be recovering at much higher rates than the carbonate reefs. The complex recovery dynamics makes it difficult to accurately predict the fate of coral reefs in the next couple of decades.

Model results for the Seychelles region (Sheppard, 2003) predict an increase in the probability of coral bleaching with extinction dates by (i) 2030 based upon warmest months; (ii) 2040 based upon warmest 3 months, and (iii) 2025 based upon the warmest quarter. Overall, with an increase in degree heating months (DHM) and mean Sea Surface Temperature, it is evident that the impact of climate change on coral reefs will be catastrophic. It is observed that the majority of reefs with high rates of recovery from coral bleaching are found in Marine Protected Areas (MPAs). These findings are significant for the future management of these areas and, areas, which appear resilient to past coral bleaching events are now being protected to ensure the survival of representative coral areas in the Seychelles.

Coastal Ecosystem degradation and Erosion

The reduction in protective coral reef cover results in a greater impact of wave energy on the shoreline. It is observed that for most of the reefs, over three modeled time periods, there has been on average an appreciable increase in energy reaching the shores over the past decade, one which matches local concerns of greater erosion of beaches and greater incursions behind beaches. More important, perhaps, is the unavoidable conclusion that the changes to come in the next decade are likely to be double those seen in the recent past.

Impacts of climate change on tourism

Climate change can have a profound effect on tourism demand and tourism resources. For example, significant changes in the climate can alter rainfall patterns, in particular increasing the number of wet days, which may cause tourists to cancel or interrupt their holidays. Similarly, an increase in coastal erosion as a result of sea level rise can reduce the attractiveness of the destination, and could also cause serious damage to coastal tourism establishments, resulting in high adaptation costs, which if passed onto the tourist can render the destination uncompetitive.

This research component used a combination of statistical analysis of climate and tourist data and tourist surveys, to explore the effects of temperature and precipitation on tourism. The results were also further analyzed in the light of socio-economic costs versus adaptation benefits. It was determined that the impact of climate change on tourism could be considered as a long-term cumulative impact, rather than a one-time event (Payet, 2005). Local environmental degradation due to anthropogenic and/or climate stressors could cause a loss in tourist welfare, which translates into loss of tourism revenue and market share, with tourists choosing alternative locations.

NIAIDE Multicriteria Analysis

By scaling up the analysis done at the study sites, the impact and relevance of climate change was evaluated for seven future development scenarios. The scenarios incorporating adaptation to long-term climate change were added to reflect the impact of external factors on sustainability. The alternative of strong conservation was preferred as the best case (without considering equity issues or stakeholder views) followed by moderate conservation. When adaptation to climate change was super-imposed on these development scenarios, an interesting pattern emerged: Moderate conservation with adaptation offered the best overall outcome in terms of sustainability. Maintaining a high level of ecosystem resilience (i.e the

Strong Conservation Scenario) may be important for reducing vulnerability to climate change, but such a strategy may not necessarily generate enough revenue for the adaptation response that may be required.

It is determined that some level of economic development is required as an important basis for investment in adaptation. Without the role of the private sector in a business economy, adaptation measures would not be possible, as these require finances. Appropriate use of natural resources, without impact on their long-term resilience function therefore turned out to be the preferred approach for generating surplus funds for adaptation options.

Capacity building outcomes and remaining needs

One PhD: The principal investigator graduated with a PhD from the University of Kalmar, Sweden in May 2006, the title of his thesis being, "Sustainability in the context of coastal and marine tourism in Seychelles". The project contributed to his research on the sustainability of tourism in small island states and its linkages to adaptation to climate change.

Support for two prospective PhD Students: Two graduate students will soon begin their PhD with a university in France, focusing on marine resource management and the impacts of climate change. These two students will be supervised by the principal investigator, as well as scientists from the University.

Support for three masters' students: Three project researchers are now pursuing distance-learning MA courses in sustainable development. They will attempt to link economic development in Seychelles with the long-term trends in climate.

Training in GIS: Special training in GIS was conducted in Seychelles for Seychelles and Comoros participants. Experts from India assisted and facilitated the training, which formed the basis for the assessment of sea-level rise and coastal flood mapping.

Training in questionnaire survey: Several training activities were organized in questionnaire preparation and conducting public surveys.

Training in beach monitoring: With the joint support of UNESCO, a national program involving hotels was launched, for the monitoring of Seychelles beaches. The database now has over 4 years of beach dynamics data and data on trends in beach degradation.

Training in coral reef monitoring: Several rangers and divers were trained in coral reef monitoring techniques to facilitate measurements of coral reef recovery in many sites around the granitic islands of the Seychelles.

Training in Environmental Economics/Global Change: A couple of distance learning courses were taken from the University College of London to improve local knowledge on the science of global change.

National communications, science-policy linkages and stakeholder engagement

The entire Seychelles team will be involved in the preparation of the Seychelles Second National Communication (SNC) and work that could not be completed under this research project will be further explored during the preparation of the SNC. The SNC was launched in October 2006, and will be implemented over 3 years, using local capacity built through the AIACC project.

The Principal Investigator of this AIACC project is also a lead author with IPCC, and one of the AIACC researchers, Mr. Wills Agricole, also contributed to the preparation of the IPCC's Fourth Assessment Report.

Policy implications and future directions

The results of the research have been incorporated in the following plans, which have been adopted by the Government of Seychelles:

- Nation-wide drainage study and investments to reduce coastal flooding
- Private-sector driven investments in coastal protection works
- Development of a GEF Adaptation project focused on water resources management.
- Development of a climate research centre within the National Meteorological Services
- Set-up of GIS-based systems for monitoring of environmental change
- Set-up of database systems to collect baseline environmental data.

7.4 References

Cesar H, van Beukering, P., Payet R.A., Grandcourt, E. 2004 Evaluation of the socio-economic impacts of marine ecosystem degradation in the Seychelles. Cesar Environmental Economics Consulting, Netherlands. 96 p. Unpublished Report.

Chen AA, Taylor MA. 2002. Investigating the link between early season Caribbean rainfall and the El Niño+1 year. International Journal of Climatology 22: 87-106

Engelhardt, U. 2000 *Fine Scale survey of selected ecological characteristics of benthic communities on Seychelles coral reefs one year after the 1998 mass coral bleaching event.* Reefcare International. Technical Report to WWF Sweden. pp. 65.

Engelhardt, U. 2004 *The status of scleractinian coral and reef associated fish c communities 6 years after the1998 mass coral bleaching event.* Final Report – March 2004. Reefcare International Marine Environmental Consulting Services, Townsville,

Focks DA, Daniels E, Haile DG, Deesling LE. 1995. A simulation model of the epidemiology of urban dengue fever: Literature analysis, model development, preliminary validation, and samples of simulation results. American Journal of Tropical Medicine and Hygiene 53: 489-506.

Hales S, Weinstein P, Woodward A. Dengue fever in the South Pacific: Driven by El Niño Southern Oscillation. Lancet 1996; 348: 1664-1665.

Hales, S., Weinstein, P., et al. 1999. El Niño and the Dynamics of Vector-Borne Disease Transmission. Environmental Health Perspectives, 107 :99-102

Intergovernmental Panel on Climate Change (IPCC). 1998. The regional impacts of climate change: An assessment of vulnerability. A special report of IPCC Working Group II, [Watson, R.T., M.C. Zinyowera and R.H. Moss (eds)]. Cambridge University Press, Cambridge, 518 pp

Intergovernmental Panel on Climate Change (IPCC). 2001. Climate Change 2001: Impacts, Adaptation, and Vulnerability, Cambridge University Press

Koopman J.S, et al., 1991. Determinants and predictors of dengue infection in Mexico. Am J Epidemiol. 133:1168-1178.

Mataki, M; Koshy.K & Nair, V 2006. Implementing Climate Change Adaptation in the Pacific Islands: Adapting to Present Climate Variability and Extreme Weather Events in Navua (Fiji), AIACC Working Paper # 34, www.aiaccproject.org, accessed 15 November, 2006

Munda, G. 1995. *Multicriteria Evaluation in a Fuzzy Environment*, Physica-Verlag, Heidelberg.

OECD 1993. *Core set of indicators for environmental performance reviews*. Paris, France.

Payet. R.A. 2003a. Integrated Coastal Zone Management in Seychelles, In: *Successes and failures of Integrated Coastal Zone Management in Eastern Africa and Island States, 1996-2001*', (Voabil, C., Engdahl, S, Eds.) Volume 2. SEACAM Publication, Mozambique. pp121-148.

Payet, R.A. & Lettington, R., 2003b. Access to Genetic Resources in Seychelles, in Kent Nnadozie et al. (Eds.), *African Perspectives on Genetic Resources: A Handbook on Laws Policies and Institutions (2003)*. Environment Law Institute, Washington DC. pp353-368.

Payet R.A. 2005. Climate policy implications of the recent ENSO events in a small island context. In: '*Climate and Africa*; Edited by Pak Sum Low' Cambridge University Press. p. 229-237.

Poveda G, Graham NE, Epstein PR, Rojas w, Quiñones ML, Valez ID, Martens WJM. Climate and ENSO variability associated with vector-borne diseases in Colombia. In: Diaz HF, Markgrtaf V, ed. El Niño and the Southern Oscillation. Cambridge University Press, 496 pp; 2000.

Santer, B. D, 2001. Projections of Climate Change in the Caribbean Basin from GlobalCirculation Models. Proceedings of the Workshop on Enhancing Caribbean Climate Data Collection and Processing Capability. Kingston, Jamaica.

Sheppard, C. 2003. Predicted recurrences of mass coral mortality in the Indian Ocean. *Nature* 425:294-297.

Sheppard, C., D. Dixon, M. Gourlay, A. Sheppard and R. Payet. 2005. 'Coral mortality increases wave energy reaching shores protected by reef flats: examples from the Seychelles.' *Estuarine, Coastal and Shelf Science 64:223-234.*

Wakeford, R. C. 2000. *Management of the Seychelles Artisanal Fishery*. PhD Thesis. Faculty of Science, Imperial College, University of London. 2000. 377 pp.

Warrick, R.A., G.J. Kenny, G.C. Sims, W. Ye and G. Sem, 1999b. The VANDACLIM simulation model: a training tool for climate change vulnerability and adaptation assessment. *Environment, Development and Sustainability*. 1 (2), 157-170.

Wilby, R.L., Dawson, C.W. and Barrow, E.M. 2002. SDSM - a decision support tool for the assessment of regional climate change impacts. *Environmental Modelling Software*, 17, 145-157.

World Bank, 2000: Cities, Seas, and Storms: Managing Change in Pacific Island Economies. Volume IV: Adapting to Climate Change: Draft Summary Version, November 13, 2000. The International Bank for Reconstruction and Development, The World Bank, Washington D.C. 71pp.

8 Capacity Building and Networking

Capacity building was a primary emphasis of the AIACC project. The project used an innovative approach to capacity building that integrates learning-by-doing, technical assistance, training, and networking. This comprehensive package of capacity building activities has near-term and long-term benefits. In the near-term, it helped to assure the success of the regional assessments of climate change vulnerabilities and adaptation that are being implemented under the AIACC project. In the longer-term, it is building capacity that is sustainable for (i) more comprehensive and more advanced assessments in the future that will continue to add to our knowledge base, (ii) for linking science and stakeholder communities to develop and apply this knowledge base to support adaptation, (iii) for contributions to national communications and adaptation planning, (iv) for contributing to international science activities such as the global assessments of the IPCC, and (v) for participating in international environmental policy processes such as the negotiations under the UNFCCC.

The capacity building activities addressed both individual and institutional capacity needs. Individuals gained capacity by acquiring experience and skills from participation in complex, multi-sector climate change assessments, working with more experienced researchers, working with experts from other disciplines, receiving training in new methods, and utilizing opportunities to present work to colleagues at international meetings, working with peers on synthesis of results from multiple projects and, for graduate students, conducting thesis research within the context of a larger research project. Institutions gained capacity by building multidisciplinary teams within their institutions to work on a complex multi-year project, building working relationships with other scientific institutions with complementary expertise and interests, and building working relationships with policy and stakeholder organizations for application of scientific knowledge to climate risk reduction.

Each of the regional studies was led by a very capable team with strong scientific expertise in disciplines relevant to the subject areas of their projects. The different teams had varying degrees of prior experience and familiarity with the assessment of climate change impacts, vulnerability and adaptation. Few had extensive experience with multidisciplinary research or assessment that encompassed physical, biological and social sciences. The most important capacity building occurred from the opportunity afforded by the AIACC regional study grants to work in multidisciplinary, multi-institutional and multi-country teams to undertake highly integrated assessments of the effects of climate on physical and human systems and how human responses can alter their vulnerability. Also important was the cross-team learning that occurred from sharing information about their experiences, methods and results in the AIACC workshops that brought together participants from multiple studies. The regional studies also benefited from technical assistance, climate change scenario support, training workshops, a supplemental small grants program, and participation in international conferences and workshops.

The contributions of each of the key components of the capacity building approach are described below.

8.1 Learning-by-Doing

Twenty-four regional assessments have been implemented under the project, each of which engages a team of participants from multiple disciplines, institutions, and countries that includes many early career scientists. In total, more than 350 experts and scientists actively participated in the assessments, including roughly 60 graduate and undergraduate students. More than 25 masters and PhD theses received support through participation in AIACC regional assessments and were completed. For many of the participants, this is their first direct participation in a multi-sector, multi-disciplinary project. By collaborating in the regional assessments with other experts, scientists and stakeholders from diverse backgrounds, the participants are learning essential skills for coordinating work by different disciplinary experts, accounting for cross-system interactions and feedbacks, integrating results across sub-regions, sectors and disciplines, and synthesizing findings in ways that are useful for adaptation planning by stakeholders.

8.2 Technical Assistance

A team of technical advisors, drawn from the IPCC and including experts from developing as well as developed countries, monitored and provided guidance to the regional assessment teams. A technical advisor was assigned to each regional study to provide guidance on project design to achieve clear objectives that serve stakeholder needs, evaluation and selection of appropriate assessment methods and tools, and general advice for implementing selected methods and tools. Teams were provided assistance with accessing climate change projection data from General Circulation Models (GCMs), validating GCM performance for their study areas, and using the GCM data to construct regionalized climate change scenarios. Teams were also provided guidance in the use of different methods and tools for assessing vulnerability to climate change, evaluating adaptation options, and engaging stakeholders in participatory assessment methods. Technical advisors reviewed and provided feedback to project teams on papers, reports and other outputs of the regional studies. Hands-on technical assistance was provided where required, but always with an emphasis on transferring the skills to the developing country assessment teams.

The technical advisors included Ian Burton, Max Campos, Paul Desanker, Tom Downing, Bruce Hewitson, Saleemul Huq, Roger Jones, Xianfu Lu, Jose Marengo.

8.3 Training

Training activities were carried out on multiple, reinforcing levels. These include global training workshops organized by the executing agencies as well as south-south training activities organized and executed by the assessment teams for themselves and colleagues in their region.

8.3.1 Global training workshops

Three global training workshops were held in the first year of the project for participants from all 24 of the regional assessments. The first of these, the AIACC Global Kick-Off Meeting, was held at UNEP headquarters in February 2002 and provided an introduction and broad overview of climate change assessment methods and an opportunity for the regional study teams to learn from each other and refine their work plans. The second global training workshop, organized in collaboration with the Tyndall Centre of the University of East Anglia and held in April 2002, provided training in the construction and use of scenarios for climate change assessment. The third global training workshop focused on methods of vulnerability and adaptation assessment. It was organized in collaboration with the Stockholm Environment Institute – Oxford and hosted by TWAS in June 2002. Experts from many leading climate change research institutions were engaged to assist with each of the training workshops, including experts from the International Center for Theoretical Physics, the Hadley Centre, Climate System Analysis Group of the University of Cape Town, CPTEC-Brazil, CSIRO-Australia, the International Institute on Environment and Development, Pennsylvania State University, National Center for Atmospheric Research, and the Potsdam Institute for Climate Impacts Research. Brief descriptions of each of the global workshops are provided below and more detailed workshop reports are available on-line at www.aiaccproject.org.

AIACC Global Kick-Off Meeting , Nairobi, Kenya, 11-15 February 2002

Over sixty investigators from the regional study teams were brought together with other invited participants for a global kick-off meeting at UNEP Headquarters in Nairobi. The meeting marked the start of a three-year effort during which participating scientists investigated vulnerabilities to climate change and climate variability within their regions, evaluated adaptation options, and engaged with private and public sector decision makers to integrate scientific information into adaptation decisions. The objectives of the meeting were to (i) encourage and facilitate reevaluation and refinement of regional study designs, (ii) develop plans for technical support and training, (iii) identify opportunities for cross-study collaborations, (iv) discuss possible AIACC products for summarizing and synthesizing methods and results of AIACC Regional Studies, and (v) sort out administrative issues related to implementing the studies.

Presentations given by invited speakers addressed general frameworks for assessing adaptation; development and application of climate and socioeconomic scenarios; integrating science and stakeholders in the assessment process; vulnerability assessment frameworks and measures of vulnerability; and advances in assessment methods. Substantial time was provided for the assembled group to discuss the issues raised by the presentatations and explore how they might be incorporated into project designs. Regional breakout sessions for project teams from Africa, Asia and the Pacific, and Latin America and the Caribbean provided opportunities to explore possible cross-study collaborations within each of the regions. Many of the study teams planned joint activities. For example, the project team from Bangkok (AIACC project no. AS07) agreed to organize a training workshop on hydrologic modeling for members of the the Philippine team (AIACC project no. AS21).

A number of issues were revisited throughout the five-day meeting. Vulnerabilities related to climate change are considered to be significant for developing countries, and yet climate change adaptation continues to be given low priority by many decision makers. Some of the factors contributing to this include (i) the prevalence of other stresses that pose immediate obstacles to development and threats to livelihoods and survival in developing countries, (ii) the perception that the stresses from climate change will be felt largely in the relatively distant future, and (iii) the cascade of scientific uncertainties that hamper attempts to predict the consequences of different actions at spatial scales that are relevant to adaptation decisions. Action on adaptation is also stalled by failures to generate and communicate information about vulnerabilities and adaptation options in forms that have ready application by, and credibility with, those who would adapt.

Meeting participants explored the implications of these and other issues for the design of regional climate change assessments that would produce information useful for adaptation decisions. Some common themes that were voiced include the importance of engaging stakeholders in the assessment process, the need to evaluate climate change and climate change adaptation in the context of other stresses, the prospects for "mainstreaming" adaptation into sustainable development planning, the advantages of focusing on broad strategies of adaptation that enhance communities' capacity to cope with climate variability and extremes, and the benefits of evaluating near term vulnerabilities and adaptation options. The meeting in Nairobi initiated a process in which the teams refined their study objectives, methods, models and scenarios that was continued at subsequent AIACC workshops.

During the meeting, input was sought for planning AIACC training and technical support activities. A number of ideas emerged from these discussions:

- Facilitate sharing of expertise across regional study teams so that teams may support and learn from each other;
- Make use of the experiences and expertise of regional study team members in training workshops;
- Supplement planned project mentoring (which largely would be via email and telephone) with on-site visits;
- Develop an interactive web resource that would allow participants to share methods, data, scenarios, working papers and other information related to their studies.

An immediate response to the input was to invite the principal investigator of several of the regional studies to present a case study at the June workshop on methods for assessment of vulnerability and adaptation. The case studies would be incorporated into the workshop curriculum and used to exemplify assessment approaches. Sharing of expertise across study teams was initiated at the kick-off meeting and was a focus of later regional workshops. Limited site visits were made to provide technical support when requested during implementation of the project. A website was established with the help of CIESIN for sharing information about methods, data and scenarios. A peer-reviewed working paper series was established and published on-line.

Climate Scenarios Training Workshop, Norwich, UK, 15-26 April 2002

Investigators from each of the AIACC regional studies met 15-26 April in Norwich, UK to participate in an AIACC project development workshop co-organized, implemented and hosted by the Tyndall Centre for Climate Change Research at the University of East Anglia. The workshop was designed to introduce the AIACC regional study partners to a wide range of techniques and tools currently available for developing scenarios for regional assessments of climate change impacts, adaptation and vulnerability and to assist each study team with the development of scenarios for use in their regional study. This was the first of two project development workshops offered by the AIACC Project.

The workshop was organized around six major themes: project objectives and scenarios needs, examples from the UK's experience, assessment methods and socio-economic futuresres, climate scenarios methods, hands-on practice with climate scenarios tools, and scenario design. The workshop emphasized the importance of selecting climate change scenario methods and tools that are appropriate to the specific objectives of a research or assessment project. Consistent with this view, a broad range of methods and tools were covered and no single method or tool was promoted for adoption by the AIACC teams.

The workshop kicked off with presentations from selected participants from AIACC assessment teams on the objectives of their project, how scenarios were expected to be used in the project, methods intended to be used for scenario construction, anticipated problems for scenario construction, and expectations for the workshop. The initial presentations indicated a strong need for guidance and information on scenario development. Common obstacles identified in the presentations and subsequent discussions include lack of long-term climate records, lack of access to climate model outputs, mismatches between the perceived temporal and spatial resolution of climate scenarios needed for impacts assessment and the resolution of global and regional climate models, and absence of adequate expertise to resolve problems of mismatched scale. The rest of the first week consisted of presentations and group discussions on the six workshop themes. Participants were also provided opportunities to meet in small groups with AIACC mentors to discuss region- or sector-specific concerns. The first week ended with a presentation by Dr. Mike Hulme of the Tyndall Centre about the problems inherent in the creation of climate scenarios and discussion of key lessons of the first week. Highlighted problems include the inaccuracy of climate models, the expense of running many global or regional climate model experiments for many future emissions scenarios, and the coarse scale of climate model outputs compared to data needs for assessment of impacts. Lessons of the first week pertained to scenario needs for impact assessments; scenario construction; integration of scenario information; quality of observed data; sensitivity studies; maintaining simplicity; and ability to work with a regional climate models.

The second week of the workshop was devoted to hands-on activities and scenario design. Participants also met several times in groups organized by region to discuss common issues and to prepare a joint presentation for the last day of the workshop. The regional presentations were given on the final day of the workshop. The presentations covered the methodologies the teams planned to use for construction of climate scenarios, the data needs, foreseen obstacles, uncertainties, and planned collaboration with other projects in their region. Nearly all the groups expressed concerns about data acquisition and quality, the need for more regional hands-on training activities related to scenarios (specifically downscaling and interpolation techniques), access to relevant peer-reviewed literature, the need for daily data, updated tools and models (specifically MAGICC/SCENGEN), and the desire for on-going assistance from regional mentors. Many participants, particularly in Africa, also raised the issue of bandwidth limitations for data access. Professor Martin Parry, Co-chair of Working Group II of the IPCC, joined the workshop for the last day to participate in the discussions and to urge all the teams to publish results from their assessments by 2005 so that they could be available for the IPCC Fourth Assessment Report.

Participants were asked to evaluate the workshop. Results of the evaluation indicate that participants were satisfied with the workshop structure, content and quality and that the majority thought that the stated objectives of the workshop were largely attained. A dissatisfaction expressed by many participants is that there was not enough time to allow them to practice with the models and tools in the IT lab. The workshop focused on introducing the participants to a wide range of scenario development methods and techniques and lab time was sufficient only to get a general sense of the capabilities of different software tools, with the expectation that participants would need further support to master selected tools following the workshop. All the tools introduced at the workshop were made available to all the participants, along with the accompanying manuals and technical notes from the workshop. Xianfu Lu of the Tyndall Centre and other AIACC mentors were available to participants during implementation of their regional studies to provide guidance in the use of the different tools.

A CD-ROM with all the course materials and additional reference materials was produced and distributed to all the AIACC teams. The materials can also be downloaded from the AIACC project website.

Vulnerability and Adaptation Training Workshop, Trieste, Italy, 3-14 June 2002

The Third World Academy of Sciences (TWAS) hosted the third training workshop 3-14 June at the International Center for Theoretical Physics in Trieste, Italy. The focus of the workshop was on methods and tools for the assessment of climate change vulnerability and adaptation. The training curriculum was developed and implemented by the Stockholm Environment Institute in collaboration with the AIACC executing agencies and technical committee. More than 100 participants from 45 countries attended the workshop.

The workshop was constructed around six major themes: vulnerability concepts and assessment, adaptation evaluation, stakeholder analysis and engagement, risk assessment and climate outlooks, sectoral impact assessment, and integrated regional assessment. The themes and emphases of the workshop reflect a "second generation" approach to climate change assessment that places understanding vulnerability at the center of assessment, engages stakeholders in the assessment process, and gives priority to generating and communicating information that is relevant to adaptation decisions of stakeholders (see START Network News, Issue No. 7, May 2002).

Plenary presentations on each of the major themes provided broad overviews of the topics and available methods for analysis. Case studies presented by selected AIACC regional study teams illustrated how these concepts have been employed in previous climate change assessments. Small breakout sessions provided more detailed treatment of specific assessment methods and concepts such as vulnerability indices, vulnerability mapping, multi-criteria evaluation, coping ranges, agricultural and water impact models, and integrated assessment models. Sessions in the computer lab provided participants opportunities to work with a selection of modeling tools. Several of the AIACC regional study teams volunteered to give presentations at the end of the first week on their planned approaches for vulnerability and risk assessment, evaluation of adaptations, and stakeholder analysis and participation. On the day prior to the last day of the workshop, every regional study team presented their study objectives, intended methods of analysis, possibilities for incorporating lessons from the workshop into their regional study, the relevance of their study to adaptation decisions, and plans for publication of results. Presentations and other workshop materials were distributed to participants on CDs and are also available on the AIACC website (http://www.start.org/Projects/AIACC_Project/aiacc.html).

During the workshop, the regional study teams consulted with AIACC mentors, invited speakers, and experts from other study teams, as well as to work with members of their own team to plan for implementation of their projects. These interactions helped move each of the projects towards more integrative, interdisciplinary assessment and proved to be an extremely valuable aspect of the workshop.

On the final day of the workshop participants discussed the challenges they would face when implementing their regional studies on climate change vulnerabilities and adaptation. The anticipated challenges include gaining skill with unfamiliar methods and tools of analysis, acquiring needed tools and data, gaining access to published scientific literature, successfully engaging stakeholders, publishing and communicating results, and synthesizing common lessons from the many individual AIACC regional studies.

The discussion highlighted a number of resources that AIACC participants could draw upon to help overcome the challenges. First among these was the considerable expertise and experience of the members of each study team, which could be supplemented by involving other experts from their region, either informally (e.g. to seek advice or to peer-review interim products) or formally (e.g. adding team members to fill gaps in knowledge). Another important resource was the expertise of members of other AIACC study teams, either within one's region or from other regions. One of the great benefits of the workshop was the opportunity for participants from the different AIACC regional studies to interact with each other, learn each other's areas of interest and competence, and discuss possible collaborations. Two of the Asia region teams had already collaborated to hold a joint training workshop on hydrologic modeling. Future regional workshops would provide further opportunities for such interactions. Plans were developed for an interactive web-resource to facilitate continued communication among study teams for sharing experiences, expertise, relevant publications, data, and results from their studies. Another resource for regional study teams to draw on are the AIACC mentors, who were available to troubleshoot problems that arose during the project, offer expert advice, review interim products and facilitate publication of papers in peer-reviewed journals.

Many study teams indicated a need for further capacity building activities such as site visits to work with researchers from other institutions or to take additional training courses. Other teams highlighted the need for additional resources to effectively engage stakeholders in their assessment activities. To meet these needs, AIACC initiated efforts to leverage additional funds and succeeded in securing a grant from USAID to supplement AIACC capacity building efforts.

Workshop evaluation forms were distributed to all regional study team participants at the beginning of the workshop. Participants were asked to score their satisfaction with different aspects of the workshop from 1 (not at all satisfied) to 5 (very satisfied). They were also asked to provide qualitative written evaluations. Overall, the responses indicate satisfaction with the workshop with respect to attainment of objectives, appropriateness of the workshop design, the quality and usefulness of most course modules, and the content of plenary presentations. Some areas of weakness in the workshop were also identified. As was the case in the climate scenarios workshop, some participants felt that the hands-on training with models for assessing impacts, vulnerabilities and adaptation was insufficient and that the training with models was too rudimentary. Others, however, found the training to be challenging due to lack of previous experience with the tools. A few participants felt that some topics were insufficiently covered to allow participants to use the presented ideas in their projects.

Discussions during the workshop led to an understanding that these shortcomings are difficult to overcome given the breadth of material being covered, the different levels of knowledge and skills of participants, and the technical depth of training that can be provided in a two-week workshop. Participants recognized that their study teams would have to be resourceful in finding ways to fill remaining gaps in the knowledge and skills required to successfully implement their research. A variety of strategies were discussed, including drawing additional experts into their teams, collaborating with other AIACC teams to obtain needed expertise, using some of their grant funds for further training, and calling upon the AIACC mentors for advice. These capacity building needs would require ongoing attention as the study teams set to work on their projects.

8.3.2 South-south training and capacity building

The global training workshops organized by AIACC gave the regional study teams broad overviews of climate change assessment methods and more detailed training in some selected methods. But many of the teams had additional training needs that could not be adequately addressed by the large training workshops. To address these needs, a number of the teams collaborated to organize small training workshops for each other. In addition, AIACC secured funding from USAID for a supplemental grant program that the teams to be used to implement self-designed capacity building and stakeholder activities.

Self organized workshops

There are several examples of collaborative south-south training activities that were organized and implemented by the AIACC regional assessment teams. The project team at the University of Cape Town held a workshop on regional climate modeling in collaboration with the Hadley Centre. Investigators from other AIACC projects across Africa participated in the training workshop. CPTEC and the Hadley Centre conducted a similar workshop in which several of the AIACC projects in Latin America participated. The

AIACC assessment team in Thailand provided training in hydrologic modeling to members of the Philippine team. In turn, the Philippines teams conducted training workshops for scientists in Vietnam, Lao PDR, and Cambodia. They have also used a portion of their grant from AIACC to provide small sub-awards for these scientists to carryout mini-assessments. The project led by CSIR of South Africa implemented a training course on conservation of biodiversity in a changing climate for land managers from across Africa. These south-south transfers of capacity are a very encouraging sign that the capacity being established by the AIACC project is not only sustainable, it can extend beyond the direct participants in AIACC.

Supplemental grants for capacity building and stakeholder participation

AIACC established a supplemental grant program to provide the teams with funds to be used to implement additional capacity building and stakeholder engagement activities. These additional activities were designed and implemented by the regional study team themselves to target their own specific needs. A grant from USAID leveraged by AIACC was used in conjunction with GEF funds to implement the supplemental grant program.

AIACC regional study teams were invited to submit proposals to apply for additional funds for capacity building and stakeholder engagement. The proposals were reviewed by the AIACC Technical Committee and award decisions were made by START, TWAS and the UNEP task manager. Twenty-four small grants were awarded, totaling nearly US$300,000 of which $130,00 was funded from the USAID grant and $170,000 was funded from the GEF grant for the AIACC project. The small grants ranged in size from $2300 to $17500.

The grants provided training and visiting scientist exchanges that have increased the scientific capabilities of developing country scientists in 35 countries to assess climate change vulnerabilities and adaptation options and have assisted them to apply these enhanced capabilities in regional assessments. Following are examples of the activities and accomplishments supported by the small grants program.

- Climate modeling and scenarios in Africa: Grants to the University of Cape Town, South Africa, and the University of Cheikh Anta Diop de Dakar, Senegal, were used to train young researchers in western and southern Africa in climate modeling, interpretation of climate model simulations, and their application to agricultural and water management; provided researchers with data, computers and data storage equipment for climate modeling; and supported an end-user dialogue workshop that brought together climate scientists, agronomists and water experts to explore potential uses of climate modeling for improved resource management.

- Climate related health risks in East Africa: Community workshops in Kenya, Tanzania and Uganda, supported by a grant to the Kenyan National Academy of Sciences, raised awareness of climatic influences on malaria and cholera risks and engaged community leaders in planning responses to manage the risks. The grant was also used to train 9 East African researchers in the use GIS tools and methods. These tools and methods are now being applied by the researchers in an assessment of climate change health risks and adaptation responses in the Lake Victoria basin.

- Water and crop modeling in West Africa: Technical staff of the Gambian Global Change Research Unit (GCRU) of the Department of Water Resources, the National Agricultural Research Institute, the Department of Agricultural Services and the regional AGRHYMET program received training in crop and water balance modeling. GCRU used their training to simulate the impacts of climate change on water balances and crop yields their evaluation of benefits and costs of climate change adaptation policies. Participants from the other Gambian agencies are applying the modeling framework for seasonal projections to be used in management planning.

- Conserving biodiversity in a changing climate: CSIR, South Africa, used results from their AIACC assessment to develop a manual for use by land managers for protecting biodiversity in a changing climate and across a landscape that is a mosaic of public and private lands and to host a training workshop. Land management officials from 10 African countries attended the workshop, which was held in February 2005. The workshop has since been developed into a distance learning course offered via the web by the University of the Western Cape.

- Watershed management in the Philippines: The University of the Philippines – Los Banos conducted a workshop to inform stakeholders of preliminary research results on the influences of climate variability and change on the Pantabangan-Carranglan watershed, discuss possible management responses, and familiarize stakeholders with the research methods and tools. The workshop has laid the groundwork for stakeholders to use research results from the AIACC project in management decisions for the watershed. Stakeholders that participated in the workshop include the National Power Authority, National Irrigation Administration, national Department of Environment and Natural Resources, and municipal agencies.

- Rice farming in the Mekong River Basin: The Southeast Asia START Regional Center, working with local researchers, conducted field surveys of farmer households, interviews with community leaders and local government officials, and focus group discussions in case study sites in Lao PDR, Thailand and Vietnam. Workshops were then conducted with community leaders, government officials and other stakeholders to share information about climate risks in the study region, get feedback and perspectives from the participants about the risks, and explore possible adaptation strategies.

- Climate risks in the Rio de la Plata basin: The University of Buenos Aires and Universidad de la Republica in Uruguay conducted national workshops for stakeholders in Argentina and Uruguay. Two documents were prepared for and distributed at the workshops, one to educate the general public about climate risks and adaptation options and a longer, more technical document for technical staffs of public and private agencies. Feedback from the workshops was used to revise the two documents, which have been published and distributed to the target audiences. The grant also supported workshops on climate change for journalists in Argentina and Uruguay. These workshops resulted in several newspaper articles and radio reports and helped to prepare journalists to cover the UNFCCC's 10th Conference of the Parties.

8.4 Networking

The AIACC project has established networks that link scientists across disciplines, institutions across institutional boundaries, countries across borders, and scientists with stakeholders. Scientists from different disciplines and institutions have built a foundation for future scientific collaborations on climate change. Scientists and stakeholders from various parts of civil society are being brought together to consider what are the risks from climate change and how we might best adapt. And participating scientists have been engaged in a variety of international science and policy activities on climate change.

The AIACC project has facilitated networking on multiple levels. Each of the assessment teams brought together persons from multiple institutions, multiple countries and diverse backgrounds. For example, one project brought together geographers, water resource specialists, epidemiologists, health researchers and public health professionals from Kenya, Uganda and Tanzania to investigate the influences of climate and climate change on malaria risks in the Lake Victoria highlands. Landscape ecologists, agriculture and food security experts, natural hazards experts and public officials from Mozambique, Malawi and Zambia worked together on climate impacts and adaptation in their region. Climate scientists, agronomists, hydrologists, agronomists and social scientists from Thailand, Cambodia, Lao PDR and Vietnam worked together to assess potential hydrologic changes in the lower Mekong and the risks to rice farmers. Climate scientists, geomorphologists, fishery biologists, marine ecologists, economists and other social scientists worked together in Argentina and Uruguay to understand flooding risks and threats to fisheries in the Rio de la Plata. In addition to the networking that was achieved within each project, AIACC also facilitated networking by engaging participants in the work of the IPCC and other international activities and through regional workshops organized by AIACC.

8.4.1 International science and policy activities

Important connections of participating investigators and institutions with a number of international organizations and activities were enhanced by the AIACC project. The Intergovernmental Panel on Climate Change (IPCC) requested AIACC's advice to identify developing country scientists to invite to scoping meetings held in 2002 to plan the IPCC's 4th Assessment Report. As a result of these consultations, a dozen of the AIACC participants were engaged in the planning of the IPCC's report. Subsequently, the IPCC invited AIACC, through START and TWAS, to nominate persons to be authors for the 4th Assessment Report. As a result, more than 30 AIACC participants are authors of this important international report, and several are coordinating lead authors. By facilitating these scientists' participation in IPCC, the project has helped them to develop professional relationships with leading researchers from around the world. AIACC scientists have also been asked to be authors for the Millennium Ecosystem Assessment (MEA) and the International Assessment of Agricultural Science and Technology (IAAST).

AIACC has organized numerous sessions at international conferences that have featured presentations by AIACC participants. These have included conferences of the International Human Dimensions Program, the Earth System Science Partnership, the Stanford Energy Modeling Forum, the UK Met Office, the Chinese Academy of Sciences and the IPCC. On several occaisions SBSTA has requested AIACC advice on developing country scientists to invite to its expert workshops and other meetings. AIACC has organized a number of side events at UNFCCC Conference of the Parties which have included AIACC scientists and senior policy makers. One such event resulted in the paper 'A plan of action to support climate change adaptation through scientific capacity, knowledge and research,' which was circulated at COP-11 and had some influence on discussions that ultimately led to the Nairobi Work Program. AIACC participants have also been regular contributors to the highly successful and well attended Adaptation and Development Days events that are held annually in conjunctions with the UNFCCC Conference of the Parties.

The AIACC project frequently receives requests for recommendations of scientists from the AIACC network to engage in various activities. Requests have come from groups such as the GEF Secretariat, UNFCCC Secretariat, IPCC, MEA, IAAST, the World Bank, research projects of the Earth System Science Partnership (e.g. the Global Environmental Change and Food Security project), the International Research Institute for Climate and Society, SEI, IIED, the Climate Change Adaptation in Africa (CCAA) program, and bilateral donors. AIACC participants are now members of GEF-STAP, the steering committee of CCAA, the management team for the ACCCA project, the IPCC Task Group on Data Scenario Support for Impact and Climate Analysis (TGICA) and leaders in developing a new global change network for Africa (AFRICANESS).

Through these and other activities, AIACC participants are now thoroughly engaged with key groups and activities internationally that relate to climate change. Several of the teams have succeeded in new grant applications to the GEF, CCAA, ACCCA, the MacArthur Foundation, the Inter-American Institute for Global Change Research, the Asia-Pacific Network and others, demonstrating that they have gained important capacity. The networks being established and nurtured by AIACC are a critically important form of capacity needed to comprehensively understand climate change vulnerabilities, evaluate integrative adaptation strategies, and share knowledge and perspectives across stakeholder groups.

8.4.2 Regional Workshops

Six regional workshops were held by the AIACC project, two each in Africa, Asia-Pacific and Latin America-Caribbean. The workshops brought together investigators from the AIACC regional studies as well as members of the science and policy communities of the host regions to share information and learn from each other about ongoing research and assessment, methodological issues, regional concerns about climate change impacts and adaptation, information needs for guiding adaptation decisions, and capacity building needs. The regional workshops also included mini-training sessions or tutorials on topics identified by the regional study teams as areas of need. Brief descriptions of the regional reports are provided below. More detailed reports and participant lists can be found on-line at www.aiaccproject.org.

First AIACC Africa Region Open Meeting and Workshop, Hartbeespoortdam, South Africa, 10-13 March 2003

The Africa Region Open Meeting and Workshop of the project Assessments of Impacts and Adaptations to Climate Change (AIACC) were hosted by CSIR on 10-13 March 2003 at the Mount Amanzi Lodge in Hartebeespoortdam, South Africa. These meetings were attended by 52 investigators from AIACC regional studies in Africa and Seychelles/Comoros and 20 guests from the region and farther a field. The guests included persons with interests in climate change science and policy from government agencies, non-governmental organizations, and national focal points of the Global Environment Facility and UN Framework Convention on Climate Change (UNFCCC).

The first day was an Open Meeting that provided an opportunity for guests to learn about the AIACC project and the ongoing AIACC regional studies in Africa. Guests and AIACC investigators engaged in discussions about the possibility of AIACC activities contributing to and benefiting from other regional research, capacity building, and assessment activities, including preparation of National Communications under the UNFCCC.

The meeting was opened by Dr. Robert Scholes of CSIR, South Africa, who put recent research directions in the context of the evolving science of climate change, from an initial focus on the climate system and responses to greenhouse gas forcing, to the potential impacts of climate change, and more recently on adaptation responses to manage the risks. Dr. Scholes was followed by Dr Simbarashe Chidzambwa from the FAO/SADC Remote Sensing Project and Dr Richard Muyungi of the Environment Division, Tanzania, who highlighted the human consequences of recent climate stresses in southern Africa and the vulnerability of Africans to future climate change respectively. These talks set the stage for presentations from each of the 12 AIACC regional studies in Africa and Seychelles/Comoros as well as panel discussions on information and capacity needs related to vulnerabilities and on adaptation opportunities, barriers and strategies.

The Open Meeting was followed by the three day Workshop for a more in-depth look at the AIACC regional studies. During the workshop, AIACC investigators presented the fruits of their first year's research, discussed the problems they have encountered, and considered strategies for overcoming some of the encountered problems. The workshop was organized into plenary sessions, parallel sessions, small group consultations, carousels (rotating brainstorming exercises) and tutorials. Most of the workshop time was devoted to parallel sessions, which were organized around the following research areas: data, trends and scenarios; climate sensitivities and impacts; vulnerability and adaptive capacity; adaptation strategies and evaluation; and policy, synthesis and AIACC future.

Investigators from the AIACC regional studies gave presentations on their research progress to date in relation to each of the first four session topics. The sessions also allowed for lengthy discussion of research methods, problems encountered and potential solutions to these problems. In the final session of the workshop, Policy, synthesis and AIACC future, participants discussed approaches for better integrating AIACC activities with policy planning and national communications, synthesizing the work of the 24 AIACC regional studies around the world, and building upon the work begun by AIACC to further enhance scientific capacity and knowledge.

The workshop also included short tutorial sessions on selected analytical approaches, models and tools that emphasized participants sharing their experiences and insights with applications of the different methods. Smalls group consultations were scheduled into the daily program and provided participants opportunities to meet with technical advisors, colleagues from other AIACC studies, and other experts.

First AIACC Asia-Pacific Region Open Meeting and Workshop, Bangkok, Thailand, 24-27 March 2003

The Asia-Pacific Region Open Meeting and Workshop of the AIACC project was held on March 24-27, 2003 at the Chulalongkorn University in Bangkok, Thailand. It was hosted by the START Southeast Asia Regional Center. Participants in the workshop numbered 68 and included investigators from AIACC regional studies in Asia and Oceania and members of the science and policy communities of the region from government agencies, non-governmental organizations, and national focal points of the Global Environment Facility and UN Framework Convention on Climate Change (UNFCCC). Also present for the open meeting and parts of the workshop were scientists attending the planning meeting for the Integrated Regional Studies of Monsoon Asia, a project of the Earth System Science Partnership that START helps to coordinate.

This workshop was organized in a similar pattern to the Africa region workshop at Hartebeespoortdam with an open meeting on day one followed by the workshop. Dr. Anond Snidvongs, Director of the START Southeast Asia Regional Center formally opened the meeting. Dr. Neil Leary, Science Director of AIACC, provided a broad overview of the AIACC project. Mr. Chartree Chueyprasit, Deputy Permanent Secretary of the Ministry of Natural Resources and Environment of Thailand, welcomed the participants and shared some comments on vulnerabilities to climate change in Thailand and activities within the country to better understand the vulnerabilities and explore possible responses. Following this were presentations by Dr. Lin Erda on climate change impacts and adaptation in China, Mr. Graham Sem on the new guidelines for UNFCCC National Communications, and Mr. Ravi Sharma on UNEP climate change adaptation projects in Asia.

At the Open Meeting, invited guests and project investigators engaged in discussion of the potential mutual benefits of interaction between AIACC studies and other regional research, capacity building and assessment activities, including preparation of National Communications to the UNFCCC. The interactions and open meeting presentations allowed guests to learn about the AIACC project and the ongoing AIACC regional studies in Asia and Oceania.

The three-day Workshop that followed the Open Meeting took a more in-depth look at the AIACC regional studies. During the workshop, AIACC investigators from each of the 6 AIACC regional studies in Asia and Oceania presented the results from their first year's research, discussed the problems encountered, and considered strategies for overcoming some of these problems. The program for the Asia-Pacific region workshop followed the same structure of plenary sessions, parallel sessions, small group consultations, carousels and tutorials as followed for the Africa region workshop.

First AIACC Latin America and Caribbean Regional Workshop, San Jose, Costa Rica, 26-30 May 2003

The first open meeting and workshop for the Latin America and Caribbean Region was held at San Jose, Costa Rica on May 27 to 30, 2003, which is the home of the AIACC project LA06. The event was hosted by the Regional Committee on Hydraulic Resources from the Central America Integration system (CRRH-SICA). Spanish-English translation was provided for the plenary sessions. Seventy-one persons attended the meeting, including members of the 6 AIACC projects in Latin America, other invited scientists and stakeholders from Latin America, AIACC staff members and Latin America AIACC technical advisors. The primary objective of the workshop was to enable the exchange of information and experiences from the 6 AIACC projects in the Latin America and the Caribbean between project investigators and other scientists and specialists.

This meeting was organized somewhat differently from the first two and began with workshop sessions first, held on May 27 to 29 followed by the open meeting on May 30. The opening session on May 27 included welcome addresses by Neil Leary, the AIACC Science Director; Ronald Arias, President for Board of Directors of FUNDECOPERACION GEF in Costa Rica; Ravi Sharma, Climate Change Program Officer, UNEP; Max Campos, Executive Secretary CRRH-SICA; and Walter Fernandes, President Academy of Sciences of Costa Rica and chairman of the science committee of the Inter-American Institute (IAI0 for global change research.

The workshop was divided into eight plenary sessions and small group consultations and interactions. Project investigators from the Latin America and Caribbean region presented progress on their AIACC research and exchanged information on research and assessment methods issues. Small group consultations provided further opportunities for this purpose. Plenary session topics include Science of Climate Change and Understanding of Global and Regional Climate; Observed Climate Change and Climate Variability; Social and Economic Information for Climate Change Projects; Climate Scenarios; Impacts, Adaptation and Vulnerability; Adaptive Capacity; Links with National Communication, Synthesis and 2nd Phase of AIACC.

The open meeting on May 30 addressed the topic of the climate change agenda in Latin America and the Caribbean. This meeting was chaired by Max Campos and Neil Leary and the speakers included Walter Fernandez, Inter American Institute for Global Change Research (IAI); Rocio Cordoba, IUCN Global Coalition for Adaptation to Climate Change; Emilio Sempris, CATHALIC-UNDP Adaptation Initiative for Central America, Cuba and Mexico; Liliana Arrieta, Global Water Partnership Associated Program on Climate Change; and Oscar Lucke, Desertification Convention, the Global Mechanism. In addition to the workshop participants, the open meeting was also attended by invited guests and stakeholders with a special interest in climate change issues in Latin America and the Caribbean.

Second AIACC Africa Region Open Meeting and Workshop; Dakar, Senegal, 24-27 March 2004

The 2nd AIACC Regional Workshop for Africa and Indian Ocean Islands was held on 24-27 March 2004 in Dakar, Senegal. The event was sponsored by AIACC and the Canadian International Development Agency (CIDA), and locally hosted and organized by Laboratoire de Physique de l'Atmosphere (LPA) at the Université Cheikh Anta DIOP de Dakar and the Ecole Superieure Polytechnique. The LPA is the home of the AIACC regional study led by Dr. Amadou Gaye. A summary of the workshop "Messages from Dakar," was published and distributed in paper copy. The report includes recommendations from the workshop, reports from the breakout sessions, and abstracts of the presentations. An electronic copy of the report is available at www.aiaccproject.org.

The workshop was attended by 95 persons, including investigators and local stakeholders of the 12 AIACC regional studies from Africa, the Seychelles and the Comoros, AIACC technical committee members, AIACC regional mentors, and several members of the international climate change community. Representatives from stakeholder constituencies from within each study area were also invited. The United Nations Environment Programme and the United Nations Framework Convention on Climate Change also sent representatives to the workshop. The first day of the workshop included welcome addresses by US Ambassador Richard A. Roth; Professor Abib Ngom, Director Ecole Superieure Polytechnique; Professor Abdou Salam Sall, President of the University Cheikh Anta Diop; Professor Amadou Gaye of the LPA; and AIACC Science Director Neil Leary.

An important objective of the workshop was to provide an opportunity for those involved in climate change issues in the region to share information generated by their project activities, discuss issues and concerns and evaluate adaptation options. The plenary sessions and small group discussions allowed for further such interactions. Plenary sessions were devoted to sharing information from the regional studies on: Climate Change Impacts & Vulnerability; Climate Variability, Changes and Scenarios; Socioeconomic Scenarios; Adaptation Opportunities and Decision-Making; Climate Change and the Development Agenda; and the Role of Stakeholders in Assessments. Small-group breakout discussion topics included: Present Day Climate Risks; Determinants of Vulnerability to Future Climate Change; Methods for Assessing Vulnerability; Methods for Climate Change Scenario Construction; Building Socio-Economic Scenarios; Lessons from Coping with Current Climate for Future Adaptation; Policy Implications of Adaptation Research; Supporting Decision-Making and National Communication with Assessments; and Integration of Adaptation into Development Policies.

Local stakeholders from the 12 AIACC study areas were invited to present on their interactions and reactions to the regional study activities and to participate in discussions about the effectiveness of stakeholder engagement in the AIACC studies. Workshop participants also discussed plans for synthesizing the broader lessons from AIACC and plans for a next phase of the project. The discussions led to a number of recommendations for an improved approach towards dealing with climate risks and increasing adaptive capacity in the Africa region. These include: (i) increase collaboration with stakeholders from local, national, regional and international organizations, (ii) actively involve UNFCCC focal points, (iii) be respectful of your stakeholders when making recommendations for action, (iv) use current climate risks as an entry point to insert climate change adaptation into public sector decision-making, (v) develop a communication strategy and (vi) find the resources to continue and extend the AIACC project.

A number of key messages emerged from the workshop. These are briefly outlined below; more complete description of the messages are given in the workshop report, *Messages from Dakar*.

- Adaptation to climate change is not just a long-term issue; adaptation is needed now; reducing vulnerability to present climate hazards is an important initial step; adaptation is best approached as a continuous process and not as discrete projects or actions; adaptation to climate change should be mainstreamed with national development processes.

- Vulnerability to climate hazards is high among those who are strongly dependent on primary resource sectors; food security, rural livelihoods, human health and water resources rank high among climate change vulnerability concerns for Africa; and place-based regional case studies in Africa are filling critical gaps in knowledge about climate change vulnerability and adaptation.

- Significant progress has been made in developing scenarios of climate change for Africa and adding capacity for climate science research in the region.

- The value of climate change research and assessment for policy application is greatly enhanced by meaningful engagement of stakeholders.

- Investments in scientific knowledge and capacity related to climate change yield high payoffs in the developing world

Second AIACC Latin America and Caribbean Regional Workshop, Buenos Aires, Argentina, 24-27 August 2004

The 2nd AIACC Regional Workshop for Latin America and the Caribbean took place on 24-27 August 2004 in Buenos Aires, Argentina. The workshop was held at the College of Sciences of the University of Buenos Aires. The College of Sciences is the home of the AIACC regional study led by Dr. Vicente Barros. The published report from the workshop, "It's raining, it's pouring,…It's time to be adapting," contains recommendations, summaries of discussions and abstracts of presentations. The repport was distributed at COP-10 in Buenos Aires and is available at www.aiaccproject.org.

The workshop was attended by 84 persons. Principal investigators and local stakeholders of the seven AIACC regional studies in Central and South America, Mexico and the Caribbean as well as AIACC technical committee members, AIACC regional mentors, and several members of the international climate change community attended the meeting. In addition, representatives from UNEP and the UNFCCC Secretariat were also present. The opening session of the workshop included addresses by the Honorable Tulio Del Bono, Secretary of Science and Technology, Government of Argentina; Honorable Atilio Savino, Secretary of Environment and Sustainable Development, Government of Argentina; Ambassador Raul Estrada Oyuela, Ministry of External Affairs, Commerce and Culture, Government of Argentina; Professor Pablo Jacovkis, Dean, College of Sciences, University of Buenos Aires; Professor Vicente Barros of the College of Science, and AIACC Science Director Neil Leary.

The workshop was organized into plenary sessions and small group breakout sessions. These sessions allowed regional AIACC investigators to share information on ongoing assessment with each other and other scientists, experts and stakeholders. Plenary session topics matched those of the Africa region workshop. Stakeholders were also given the opportunity to present their views on stakeholder interactions and engage in a discussion on the effectiveness of such interactions. Finally workshop discussions focused on extracting the broader lessons learnt from the knowledge generated from the AIACC project.

Important messages that emerged from this workshop include:

- The climate is changing and is expected to continue to change, partially as a result of human causes;
- Climate risks are widespread in Latin America and the Caribbean and threaten human health, food production, water resources, forests, biodiversity, rural livelihoods, and coastal populations, infrastructure, fisheries and estuaries;
- Adaptation is needed now and there is sufficient knowledge to act;
- Adaptation to climate change should be integrated with development policies;
- Advances in knowledge about climate change vulnerability and adaptation continue to be needed particularly at local and regional scales in developing countries;
- Important scientific and technical capacities exist in Latin America and the Caribbean, but further investments in capacity and regional cooperation are needed;
- Partnerships among policy, practitioner, stakeholder and science communities are needed for effective adaptation; mobilizing and sustaining these partnerships are important for building adaptation capacity;
- AIACC is filling important needs for advancing knowledge, capacity and networks that complement other efforts in Latin America and the Caribbean

Second AIACC Asia-Pacific Regional Workshop, Manila, Philippines, 2-5 November 2004

The Second Regional Workshop for Asia and the Pacific was held on 2-5 November 2004 at the Traders Hotel in Manila, Philippines. The host was the College of Forestry and Natural Resources of the University of the Philippines's at Los Baños. The College of Forestry is home to the AIACC project headed by Dr. Rodel Lasco. The workshop was attended by 98 persons, including AIACC project investigators from Mongolia, Thailand, China, Sri Lanka and Fiji, representatives of national ministries, other regional assessments, public and private stakeholders and scientific communities.

The workshop opened with remarks by the workshop co-chairs, Rodel Lasco and Neil Leary. This was followed by addresses from Professor Wilfredo David, Chancellor, University of the Philippines Los Baños, who spoke about the need to manage and adapt to the impacts of climate; Honorable Michael Defensor, Secretary of the Department of Environment and Natural Resources, Government of the Philippines, who emphasized the importance of the AIACC project for the Filipino farming community; Ambassador J. Enkhsaikhan, GEF Council Member, Mongolia, who conveyed the message of Len Good, the GEF CEO, on the importance of the AIACC project in developing scientific and technical capacity to deal with the impacts of climate change; Professor Mohamed Hassan, Executive Director, Third World Academy of Sciences (TWAS), who discussed the AIACC project as an excellent example of fulfilling the strategic objectives of TWAS; and Honorable Estrella Alabastro, Secretary of the Department of Science and Technology, Government of the Philippines. Plenary and breakout sessions followed the same structure as used for the workshops in Africa and Latin America.

9 Project Outputs and their Use

The major outputs of the project can be grouped into three categories: the regional climate change assessments, human and institutional capacity; and scientific knowledge. The outputs and their use are described briefly below.

9.1 Regional Climate Change Assessments

Twenty-four climate change assessments were completed under the AIACC project. Each of the assessments produced a technical report for distribution in their regions, numerous publications and various other outputs for communication to stakeholders and the public. The technical reports are available on-line at www.aiaccproject.org. The AIACC climate change assessments are being used to provide a stronger scientific basis for the vulnerability and adaptation assessments of countries' Second National Communication to the to the UNFCCC, to inform national delegations to the UNFCCC Conferences of the Parties about key issues, to raise awareness of stakeholders and the general public about climate change vulnerability and adaptation, to advance scientific understanding and inform the 4th Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) on these issues as they pertain to developing countries, and to inform the consideration and development of adaptation strategies at local and national scales.

All 24 AIACC teams established contacts and shared scientific outputs with entities responsible for National Communications and National Adaptation Programs of Action (NAPA). Many of the teams have been asked to formally contribute to National Communications and NAPAs and several are in key leadership roles for planning and preparing their country's 2nd National Communications. Interactions between AIACC teams and stakeholder groups are continuing and contributing to adaptation planning. Selected examples of how AIACC outputs are contributing to National Communications, NAPAs and other activities are described below. Additional details and examples can be found in the summaries of the regional assessments presented in Chapters 4-7 of this report and in the techncial reports of the individual assessments.

- The South African biodiversity project (AF04) prepared South African delegations to UNFCCC COPs with briefings and briefing papers. Two of the scientists from the project are members of the South African delegation and have participated in UNFCCC negotiations, drawing upon results from their assessments. Results from their assessment of climate change threats to biodiversity and strategies to adapt conservation practices formed the core of a training workshop that the project team organized and implemented for conservation professionals from across Africa. The course is now available on-line through the University of the Western Cape (http://planet.uwc.ac.za/nisl/AIACC) and will be used as a resource for developing a similar course at the University of Dar es Salaam. Follow-on work from the assessment is applying the methods to other sub-regions and examining how results from case studies can be used to form a national strategy for biodiversity conservation. Results of the analysis are included in the IPCC's 4th Assessment Report.

- Downscaled regional climate change scenarios for Sub-Saharan Africa developed by one of the AIACC projects (AF07), are being applied by a variety of users. Early versions of the scenarios were used by several AIACC projects in Africa. The scenarios have also been used by other projects in South Africa for impact assessments of agriculture and water resources in major river catchments and by the municipalities of Durban and Cape Town to evaluate and plan adaptation strategies. A project in Zambia on climate change impacts on hydropower generation is using the scenarios and it is expected that this analysis will be included in the next National Communication from Zambia. The project team is now providing technical support to assist new pilot adaptation actions under the program Advancing Capacity in Support of Climate Change Adaptation (ACCCA) to use the scenarios developed under the AIACC project. Discussions are also under way for supporting use of the scenarios for assessments in Botswana and other countries of southern Africa. The scenarios figure prominently in the IPCC's 4th Assessment Report.

- Project outputs and methods of the Sudanese project (AF14) have been used in development of Sudan's NAPA and are also being used in the planning of Sudan's Second National Communication. The project validated the effectiveness of community development projects that apply a sustainable livelihoods approach for increasing resilience to drought. As a result, community development projects that take a holistic approach to improving and diversifying rural livelihoods, protecting and sustaining natural resources, and strengthening community institutions are recommended as a model to be replicated for adapting to drought and climate change.

- Early results from the Nigerian project on food security (AF23) were incorporated into Nigeria's First National Communication, which was submitted in 2004. The principal investigator is a member of Nigeria's National Committee on Climate Change and is introducing results of the project in preparatory discussions for the Second National Communication. The project identified problems with seasonal weather forecasting practices in West Africa that impede use of the forecasts by farmers. The project demonstrates that more useful and higher skill forecasts are possible and provides recommendations to improve the communication to and use of forecasts by farmers.

- The Miombo region project (AF38) developed methods and tools for assessment of climate change vulnerability and adaptation (PRIVA) that are being made available to Least Developed Countries (LDCs) via regional workshops of the UNFCCC. The approach and tool are intended to assist LDCs to develop National Adaptation Programs of Action (NAPA). Insights from application of assessment and stakeholder participation methods of the project informed and were incorporated into the NAPA guidelines of the LDC Expert Group. The project has made active contributions to NAPA activities in Malawi, Mozambique and Zambia and project participants are working with Ministers and Principal Secretaries in Malawi on follow-up activities for improved management of climate risks.

- The Gambia and South Africa project (AF47) produced some of the few available estimates of benefits and costs of climate change adaptation and their analysis is reviewed in the IPCC 4th Assessment Report. The Gambian partner in the project, the Department of Water Resources, has submitted a proposal with UNEP for implementation of Gambia's NAPA, which will draw heavily from the AIACC project experience and results. The South African partner, the Energy Research and Development Center, is a member of the South African National Committee on Climate Change and regularly briefed the committee about activities and results from the AIACC project.

- The assessment of adaptation strategies performed by the Mongolian project (AS06) are feeding into new activities to promote climate change adaptation, including projects in Mongolia under the Netherlands Climate Change Studies Assistance Program (NCCSAP) and the ACCCA program. The project was coordinated by an agency of the Ministry of Nature and Environment, which is the body responsible for Mongolia's national communication. Consequently, findings from the project are assured of being incorporated into the Second National Communication. The project documented a number of observed climatic and environmental trends that are included in the IPCC's 4th Assessment Report. One of the lead investigators was recently named vice-chair of the Mongolian National Committee on Global Change Research, a new committee charged with stimulating and coordinating climate change and other global environmental change research, and is also teaching masters level students about climate change assessment at the Mongolian National University.

- The Kenyan participants in the East African project on malaria and cholera (AF91) have received new funding from ACCCA to build upon their work and apply lessons to adaptations that can reduce health risks that are related to climatic factors. The Tanzanian participants at the University of Dar es Salaam have received funding from CCAA for a major new adaptation project, a grant from the MacArthur Foundation to develop masters level courses on biodiversity conservation and climate change that make use of the capacities that have been enhanced by their participation in the AIACC project, and have been invited by the MacArthur Foundation to submit another proposal to assess climate change and biodiversity in the Albertine Rift countries. The University of Dar es Salaam was also recently selected to be the new host of the Pan-African START Secretariat and will be coordinating START activities for all Africa and will work with START in implementing a new African Climate Change

Fellowship Program that has been funded by the International Development Research Centre. Findings from the malaria-cholera project are included in the IPCC 4th Assessment report.

- The Principal Investigator of the Lower Mekong project (AS07) is a member of the National Climate Change Committee of Thailand and an associate investigator is a member of the working group for development of the national climate change strategy for Thailand. The project will have an impact on Thailand's climate change strategy through these connections. The lead institution for the project, which is based at Chulalongkorn Univeristy in Thailand, provided guidance and training to Vietnamese, Cambodian and Lao PDR participants that increased their capacity for vulnerability and adaptation assessment. The lead institution is now part of the technical support team for the ACCCA project and will be transferring the capacities built in the AIACC project to others in the Asia region. The center at the University of Chulalongkorn was recently contacted by the Rockefeller Foundation to invite a bid for work on climate change adaptation in Asian cities and is also working with the university to develop a graduate degree program on global environmental change.

- The Philippine-Indonesia project team (AS21) includes the chair of the Philippine Interagency Committee on Climate Change, who is leading the preparation of the Philippines' Second National Communication. Activities and results of the project have shaped preparations for the second national communication and are expected to figure prominently in the communication when it is completed. The project team is working with the Philippine Atmospheric, Geophysical and Astronomical Administration on new work that will build upon project results. The team will also be implementing a pilot adaptation project under the ACCCA program that is an extension of the AIACC project. Findings from the project are included in the IPCC 4th Assessment Report. Capacity from the project was transferred to colleagues in Vietnam, Lao PDR and Cambodia through a training workshop and assistance with assessment activities in those countries.

- The project on coastal vulnerabilities of the Buenos Aires region (LA26) had direct input to the Environmental Agenda for Argentina that was developed by the Secretary of Environment and Sustainable Development. Members of the project team have been assigned the task of preparing the assessment of vulnerability of the coastal area of Buenos Aires for Argentina's Second National Communication and will draw heavily from the project's findings. The project also worked with Fundacion Ciudad, a community NGO, to communicate climate change risks and risk management strategies to inhabitants of flood prone areas of Buenos Aires, including publication of a booklet for the general public, *El Cambio Climatico y la Costa Argentina del Rio de la Plata.*

- Results from the Argentine-Brazil-Uruguay Pampas agriculture project (LA27) were the basis for a section of Uruguay's Second National Communication on the vulnerability of mixed crop and livestock systems. Uruguay submitted its Second National Communication in 2004.

- The Mexico-Argentina project (LA29) will have direct input to Mexico's Third National Communication as the two project PIs are members of the team that will prepare the communication. The project produced a number of information brochures for the public to raise awareness and understanding of climate change impacts, vulnerability and adaptation, one of which was distributed by the government in Mexico City's subway system. The project has also been featured on television and radio programs in Mexico and has developed a catalogue of adaptation strategies that are publicly available. Involvement of policy makers and stakeholders in workshops of the project has led to two new projects that will apply methods and results of the project to promote adaptation in Tamaulipas and Veracruz, Mexico. A lead investigator of the project made a presentation to the Mexican Congress on climate change adaptation and research needs.

- The Second National Communication of Jamaica will include results of the dengue assessment performed for the Caribbean (SIS06) and efforts are being made to encourage other Caribbean islands to incorporate relevant information in their communications. One of the recommendations of the project was to implement an early warning system that could be used to better manage dengue risks when climate variations and other factors raise the risk of infection. The Director of the Disease

Prevention and Control Division of the Ministry of Health in Jamaica has indicated interest and discussions are being pursued about possible implementation.

- Development of the Second National Communication of the Seychelles was launched in October 2006. The entire Seychelles project team (SIS90) is involved in the national communication and local capacity built by the project and knowledge generated by the project will make important contributions to the communication. The project team has conducted meetings with hotel developers, contractors and other stakeholders on coastal adaptation.

9.2 Human and Institutional Capacity

An important output of the AIACC project is enhanced capacity that enables scientists, technical experts and scientific institutions of developing countries to (i) undertake comprehensive, advanced climate change assessments that add to our knowledge base, (ii) link science and stakeholder communities to develop and apply this knowledge base to support adaptation, (iii) contribute to national communications and adaptation planning, (iv) contribute to international science activities such as the global assessments of the IPCC, and (v) participate in international environmental policy processes such as the negotiations under the UNFCCC. The approach to capacity building taken by the AIACC project, described in Chapter 8, combined learning-by-doing, technical assistance, training, and networking and addressed both individual and institutional capacity needs.

The teams established working relationships with stakeholder groups that have yielded common understanding of climate change vulnerabilities and adaptation options. These working relationships, documented in the technical reports of the regional assessments, represent important capacity for continued application of scientific knowledge to support adaptation and National Communications. The participation of 30 AIACC scientists as authors of the IPCC AR4, and more than 100 citations of AIACC publications in the AR4, amply demonstrate the use of AIACC capacity in international science activities. The various south-south training activities that were spawned by AIACC give evidence that capacity developed by the project is being transferred to others.

Evidence of the enhanced capacity and its uses are multiple. The primary use of the capacity built by the project is in the execution of the AIACC climate change assessments themselves. The technical assistance, training, networking and other support helped to assure the success and improve the quality and credibility of the results of the assessments. The substantial output of peer-reviewed scientific publications, and extensive citations of AIACC publications in the new IPCC AR4, described in the next section, demonstrates the high scientific capacity of the project participants for research and assessment that have expanded the knowledge base.

Part of the institutional capacity enhanced by AIACC is represented by the working relationships established by the project between science and stakeholder organizations in each of the study regions. These working relationships, documented in the technical reports of the regional assessments, represent important capacity for continued application of scientific knowledge to support National Communications and adaptation planning. Many such applications are described in the previous section. The enhanced capacity of the institutions that participated in AIACC is also being used to further enhance and transfer capacity in developing countries through new training workshops, new graduate level courses, stakeholder outreach and public education.

The enhanced skills and knowledge of the AIACC teams have contributed to the IPCC's 4th Assessment Report, which includes 30 AIACC participants as lead authors, 8 of them as convening lead authors. Several of the AIACC alumni are taking up leadership positions in the climate change community, for example as members of the steering committee of the IDRC/UKDFID Climate Change Adaptation in Africa program, the planning committee for AFRICANESS (a new African global change network), the Pan-African Committee of START, the IPCC Task Group on Scenarios for Climate Impact Assessment and national committees on climate change and global change. Three AIACC participants are co-chairing an important IPCC conference on new climate change research that is being hosted by the AIACC SIS09 project team in Fiji. Two of the AIACC teams are part of the project management team for the new ACCCA program and are providing technical support to assist other groups to execute adaptation projects. Many are applying their abilities in new research, assessments and adaptation pilot actions being supported by the GEF, CCAA, ACCCA, NCCSAP, IAI, the MacArthur Foundation and APN, as well as activities funded by national governments of developing countries.

The individual and institutional capacity built by AIACC, while vulnerable, is sustainable. A number of factors contribute to the sustainability of this capacity. First, the climate change assessments were executed by scientific institutions that have long-term commitments to research, education and training that are related to climate change hazards. These institutions have a strong self-interest to further invest in and use the capabilities that have been enhanced by the AIACC project, and their success in applications for new grants from various donors is evidence of this. Second, individual capacity building and training efforts targeted early-career scientists. By engaging early-career scientists in climate change assessment and assisting them to develop capabilities to excel in this field, it is expected that many will focus their future research, assessment and policy activities to address problems of climate change. Third, the success that AIACC has had in developing cross-institutional collaborations and engagement of participants in IPCC, MEA, IAAST and the global change research programs has developed networks that will serve to keep the AIACC participants engaged in climate change assessment work, both the individuals and the institutions.

9.3 Scientific Knowledge

The output of scientific knowledge from the AIACC project, represented by publications from the project participants, is substantial and exceeds what typically is achieved by comparable projects. As of the time of the writing of this report, peer-reviewed publications from the AIACC project exceeded 100. More than 60 papers were published in peer-reviewed journals and books and more than 40 in the peer-reviewed *AIACC Working Papers* series (the working papers are available on-line at http://www.aiaccproject.org). The project also produced two books, *Climate Change and Vulnerability* and *Climate Change and Adaptation*, which are scheduled to be published by Earthscan before the end of 2007. These books are collections of peer-reviewed papers from the AIACC climate change assessments. In addition to peer-reviewed publications, more than 100 other publications were produced by the projects, including 25 student theses that were completed with support from AIACC. The technical reports from the climate change assessments also provide detailed information about the scientific methods and findings of the assessments. Complete reference information for the publications is provided in Annex A.

The publications help to fill important gaps in the scientific literature on climate change vulnerability and adaptation in developing countries. There are more than 100 citations to AIACC publications in the new IPCC 4th Assessment Report, despite the fact that many of the AIACC publications came out too late to be included in the report. Many of the publications also are being used by national communications.

10 Achievement of Objectives

Prior chapters of this report document the activities and results of the AIACC project. Here we present indicators of performance of the project with respect to the specific objective and intended outcomes of the project logical framework.

The overall objective of the AIACC project is to enable developing countries to respond effectively to climate change risks by enhancing science capacity, assessment techniques and information targeted to the most vulnerable regions and sectors where capacity is needed. Progress toward the objective is to have been achieved by attaining three outcomes:

1. Enhancement of scientific capacity in developing countries to assess climate change impacts, vulnerability and adaptation, which is needed to support National Communications and to enable more effective participation in international scientific activities such as the assessments of IPCC;
2. Advancement of scientific understanding of climate change impacts, vulnerability and adaptation; and
3. Improvement of links between science and policy communities to enable adaptation planning and action.

For each of the intended outcomes, we have identified indicators to measure performance, characterized baseline levels, present measures of progress achieved by the project with respect to the indicators and identified sources of information for the measurements.

10.1 Enhancement of Scientific Capacity

Indicator 1.1: Successful completion of climate change vulnerability and adaptation assessments by in-country experts.

Baseline: Vulnerability and adaptation research and assessment in developing countries is less than needed according to IPCC; assessments are often highly dependent on external expertise for success.

Performance: 24 climate change vulnerability and adaptation assessments were successfully completed by in-country teams of scientists and experts. The teams were responsible for the design, implementation and management of their assessment activities, including technical analyses and synthesis. The teams received technical assistance from the AIACC project, but in all instances the developing country teams conducted the work.

Sources: Final reports and published papers of the climate change assessments; the final reports are available on-line at www.aiaccproject.org.

Indicator 1.2: Scientific productivity of the participants and quality of scientific outputs.

Baseline: Publication in peer-reviewed literature not as common in scientific communities of developing countries as in developed.

Performance: More than 200 scientific publications were produced by the AIACC participants, including more than 60 papers in peer-reviewed journals and books and more than 40 peer-reviewed papers in the on-line *AIACC Working Papers*. There are more than 100 citations to AIACC publications in the IPCC 4th Assessment Report. Publication in peer-reviewed literature and citation of many of the papers in the new IPCC 4th Assessment Report are indicators of the quality of the output.

Sources: A list of publications with full bibliographic details is given in Annex A of the report; the AIACC Working Papers are available on-line at www.aiaccproject.org.

Indicator 1.3: Participation in international science activities.

Baseline: Participation of developing country scientists and experts in international science activities is generally low.

Performance: 30 AIACC developing country participants served as lead authors/convening lead authors of the IPCC's 4th Assessment Report; several were authors of the Millennium Ecosystem Assessment; several are authors of the International Assessment of Agricultural Science and Technology; numerous invited papers were presented at international science meetings by AIACC participants, including expert workshops of the IPCC, the International Human Dimensions Program Open Meeting (Bonn, October 2005), International Symposium on Arid Climate Change and Sustainable Development (Lanzhou, China, May 2005), Forum on Regional Climate Monitoring, Assessment and Prediction for Asia (Chinese Meteorological Agency, Beijing, April 2005), 2nd International Workshop on Climatic Prediction and Agriculture (Switzerland, May 2005), 16th Global Warming International Conference (New York, 2005), the International Conference on Stabilizing Greenhouse Gases (Hadley Center, UK, February 2005), 14th Asia-Pacific Seminar on Climate Change (Sydney, September 2004), Vulnerability to Climate Stress – Local and Regional Perspectives (Nairobi, ICRAF, January 2005), Global Forum on Sustainable Development (Paris, November 2004), International Symposium on Climate Change (Beijing, 2004), Second International Conference on Climate Impacts Assessment (Germany, June 2004), Second International Regional Climate Modeling Workshop (ICTP, Italy, 2004), the International Human Dimensions Program Open Meeting (Montreal, October 2003), and the Stanford University Energy Modeling Forum Workshop on Climate Change Impacts (Colorado, July 2003).

Sources: Author lists from IPCC, MEA and IAAST; progress reports from AIACC.

Indicator 1.4: Leadership in international science activities.

Baseline: Developing country leadership in international science activities is generally low.

Performance: 8 AIACC participants are Coordinating Lead Authors for the IPCC 4th Assessment Report. 4 are members of the IPCC Task Group on Data Scenario Support for Impact and Climate Analysis (TGICA) (TGICA), which is a cross-working group body that plans for data, scenario and research needs of the IPCC. 3 are members of the science advisory board and 1 is a senior program manager of the IDRC/DFID Climate Change Adaptation in Africa (CCAA) program. A few are members of the scientific committees of the projects of the Earth System Science Partnership (ESSP), including the Global Environmental Change and Food Security Project (GECAFS). The Institute for Resource Assessment (IRA) at the University of Dar es Salaam, a participant in the AIACC AF91 project, has recently been selected to host and direct the Pan-African START Secretariat (PASS) and will coordinate START science and capacity building activities in Africa. The PI of the AIACC AF90 project was recently named Vice President for Research of the Agricultural Research Center of the Ministry of Agriculture in Egypt, which is composed of numerous research institutes and labs. Several AIACC participants are members of the steering committee of AFRICANNESS, a new African science network on global change. Several have organized and chaired important conferences and conference sessions, including the upcoming IPCC conference on Integrating Analysis of Regional Climate Change and Response Options to be held in Fiji in June 2007.

Sources: Author list and TGICA membership list from IPCC, IDRC CCAA program office, ESSP, AFRICANNES Secretariat.

Indicator 1.5: Recognition as centers of excellence for climate change and V&A research

Baseline: Several centers of ecellence exist in developing countries but are often dependent on a small number of experts; centers often lack resources to participate effectively in international science activities.

Performance: Several of the research groups have enhanced their capacity and scientific reputations through their participation in AIACC. As a result they are having increased success in grant applications, are increasingly invited to participate in international research activities and are being involved in new projects to provide technical support to other groups. These centers include CSAG at University of Cape Town (several new grants, part of technical support team for ACCCA, recently made a research node in the START system), IRA/University of Dar es Salaam (recently named new host of PASS, has received new grants from IDRC/CCAA and MacArthur Foundation, and will be managing a new fellowship program for climate change adaptation in Africa), Atmospheric Physics Laboratory at Cheikh Anta Diop University in Dakar (active in climate change research in West Africa), College Forestry of the University of the Philipinnes at Los Banos (new grant from ACCCA), Department of Meteorology of University of Buenos Aires (new grants, active participant in IAI), Department of Meteorology of the National Autonomous University of Mexico, University of the West Indies (working with health ministries on early warning systems), Chulalongkorn University/START Southeast Asia Research Center (new grants, part of technical support team for ACCCA project), HCENR Sudan (science advisory board of CCAA, leadership role in Sudan's NAPA).

Sources: Final reports of the climate change assessments, AIACC progress reports.

Indicator 1.6: Initiation of south-south capacity building activities

Baseline: Most capacity building activities are delivered to south by northern based institutions

Performance: Several AIACC project teams organized and implemented training and other capacity building activities for others in their region. Chulalongkorn University in Thailand provided training in hydrologic modeling to participants in from University of the Philippines and will be organizing training workshops and technical support for new ACCCA projects in Asia. The University of Philippines and Chulalongkorn University provided training in vulnerability and adapatation assessment methods to colleagues in Cambodia, Lao PDR and Vietnam. CSIR-South Africa conducted a training workshop for conservation professionals and has made the training available via distance learning on the internet. CSAG-UCT helped to implement the AIACC training workshop on climate change scenarios, organized a training workshop on regional climate modeling, and will be organizing training workshops and technical support for new ACCCA projects in Africa. The University of the West Indies assisted IAI with implementing a training workshop on human health and climate change. IRA/University of Dar es Salaam is developing new masters' level courses on biodiversity and climate change that are to be offered to early to mid-career professional in Africa through a grant from the MacArthur Foundation.

Sources: Final reports of the climate change assessments; AIACC progress reports; ACCCA website.

Indicator 1.7: Number of persons from developing countries who benefited from learning-by-doing, mentoring and training activities.

Performance: >300 developing country scientists, experts and stakeholders from 108 institutions and 50 developing countries participated in the AIACC regional climate change assessments; >100 early career scientists and experts were trained in AIACC training workshops.

Sources: AIACC progress reports; AIACC workshop reports.

Indicator 1.8: Number of student theses supported.

Performance: 25 student theses received support through their participation in AIACC climate change assessments and were completed.

Sources: Reported by Project PIs; list of publications in Annex A.

10.2 Advancement of Scientific Understanding of Climate Change Impacts, Vulnerability And Adaptation

Indicator 2.1: Scientific publications.

Baseline: Major gaps in knowledge about impacts, vulnerability and adaptation in developing countries.

Performance: More than 200 scientific publications were produced by the AIACC participants, including more than 60 papers in peer-reviewed journals and books and more than 40 peer-reviewed papers in the on-line *AIACC Working Papers*.

Sources: A list of publications with full bibliographic details is given in Annex A of the report; the AIACC Working Papers are available on-line at www.aiaccproject.org.

Indicator 2.2: Citation of publications in scientific literature

Performance: There are more than 100 citations to AIACC publications in the IPCC 4th Assessment Report. Most of these are in the report of Working Group II, Impacts, Adaptation and Vulnerability.

Source: IPCC 4th Assessment Report.

Indicator 2.3: Develop and demonstrate assessment methods appropriate to circumstances of developing countries.

Baseline: methods appropriate to developing country circumstances sometimes lacking.

Performance: Innovative methods developed and demonstrated include high resolution regional climate change scenarios (AF07), rural livelihoods vulnerability assessment (AF14, AF92, LA29), vulnerability indices (AS07, LA29), integrated assessment of vulnerability and adaptation (AF38, AS25), benefit-cost analysis of adaptation (AF47), multi-criteria analysis of adaptation (AS06, AS21, AS25, SIS06). AIACC has worked with UNFCCC Secretariat to include methods from the AIACC studies in the UNFCCC Compendium of Methods for Impacts, Vulnerability and Adaptation and AIACC methods figure prominently in the compendium.

Sources: Final reports of the climate change assessments; AIACC synthesis papers (chapters 2 and 3 of this report) and books. Methods also documented on AIACC Data, Methods and Synthesis website (http://sedac.ciesin.columbia.edu/aiacc/) and in the UNFCCC Compendium on Methods and Tools to Evaluate Impacts of, Vulnerability and Adaptation to Climate Change (http://unfccc.int/adaptation/methodologies_for/vulnerability_and_adaptation/items/2674.php).

10.3 Improvement of Links Between Science and Policy Communities

Indicator 3.1: Partnerships established between scientific and stakeholder organizations.

Baseline: Working relationships between scientific and stakeholder organizations are rare.

Performance: All 24 assessments developed working relationships with stakeholder and scientific organizations to collaborate in sharing, generating and communicating information about climate risks and adaptation responses. Examples: AS06 conducted workshops in Mongolia that included herders, herders' organizations and government officials from local, provincial and national offices and are continuing to work with these groups in new adaptation projects. AS21 in the Philippines conducted workshops that included representatives of local community groups, farmers, National Power Authority, National Irrigation

Authority and Department of Natural Resources and is continuing to work with these groups on solutions to water management, forestry and risk reduction. AF14 worked with local development organizations and community organizations to evaluate performance of past development projects and will continue to work with these groups in Sudan's NAPA and other activities. AF91 involved community health workers in their work in Kenyan highlands and will work more closely with such workers in a new project on managing malaria risks. SIS06 worked closely with the Jamaican Department of health and is discussing with them the possibility of establishing an early warning system for Dengue. SIS90 is working with developers and contractors on problems of coastal erosion in the Seychelles. LA26 is working with a community NGO on coastal flood risks in Buenos Aires. LA32 is working with artisanal fishing communities of the Rio de la Plata on problems of livelihood security related to variability in the fishery. More examples can be found in the summaries of the climate change assessments (Chapters 4-7) and their final reports.

Sources: Final reports of the climate change assessments.

Indicator 3.2: Contribution to national communications and NAPAs.

Baseline: Scientific input to national communications and NAPAs often less than needed.

Performance: All 24 AIACC teams established contacts and shared scientific outputs with entities responsible for national communications and NAPAs. Many of the teams have been asked to formally contribute to national communications and NAPAs and several are in key leadership roles for planning and preparing national communications. Chapter 9 on outputs and their uses gave some examples, and there are many more.

Sources: Final reports of the climate change assessments.

Indicator 3.3: Participation in international and national policy activities.

Performance: AIACC climate change assessment teams contributed to NAPA preparations in Sudan (AF14), Malawi, Mozambique, Zambia (AF38) and The Gambia (AF47) and also contributed to the NAPA guidelines and methods development through the Miombo region project (AF38). Several AIACC investigators co-authored technical papers for the Adaptation Policy Framework, drawing upon their AIACC experiences. AIACC has worked with the UNFCCC Secretariat to provide relevant experts to participate and present in SBSTA expert workshops and to incorporate methods used by the AIACC teams into their compendium of methods. AIACC investigators have participated in policy conferences such as the Adaptation and Development Days event held annually at the UNFCCC Conference of the Parties, Adaptation Research Workshop sponsored by UNEP/SEI/IIED in New Delhi, November 2003; the Adaptation Science and Policy Conference in Beijing, 2004; the Sustainable Development Summit sponsored by TERI in New Delhi, February 2005; and numerous national policy dialogues (e.g. Mongolia, Mexico, Argentina, South Africa). AIACC participants were active in SBSTA negotiations that led to the Nairobi Work Program. AIACC organized side events at COPS 8, 9, 10 and 11. This included the event *"Science in Support of Adaptation to Climate Change"* at COP-10 which was co-sponsored by UNEP, START, TWAS and the Government of Argentina, was opened by Ambassador Estrada Oyuela of Argentina and Bakary Kante of UNEP and was attended by a standing room only audience of more than 120 persons. The event resulted in a policy paper that was circulated at the COP (see AIACC Working Paper No. 23, 'A plan of action to support climate change adaptation through scientific capacity, knowledge and research'). More examples are given in Chapters 4-7 and 9, as well as in the final reports of the climate change assessments.

Sources: Final reports of the climate change assessments; AIACC progress reports.

11 Conclusions and Recommendations

Conclusions about scientific findings of the AIACC project are in chapters 2 and 3. Here, in the closing chapter of the report, we present conclusions and recommendations about implementation of the project.

11.1 Achievements and Remaining Gaps

The AIACC project made important progress on the objectives of advancing knowledge, enhancing scientific capacity and improving links between science, policy and stakeholder communities, as documented in this report. However, substantial gaps remain. There are many questions about climate change vulnerability and adaptation in developing countries that remain unanswered, or only partially answered, and new questions are emerging that are critical for adaptation planning. For many parts of the developing world, there is still very little research and published literature on climate change. The distribution of capacity remains patchy. There are some centers of true excellence and many institutions that have demonstrated strong capabilities for climate change assessment. Most of these are in what might be called the upper and middle class countries of the developing world, while the least developed countries generally lack institutions with strong capabilities for climate change assessment. But even in the wealthier developing countries, capacity is limited to a relatively small number of institutions and is vulnerable to being lost. Some important links were formed by AIACC projects between scientific, policy and stakeholder communities. But they are few compared to the enormous need.

Some of the important gaps in knowledge include:

- Characterization of the range of future exposures to climate hazards at regional and finer spatial scales that are important for adaptation decisions;
- Identification and prioritization of climate hazards that are of highest concern for different sectors, systems, places and groups and investigation of how these hazards will change with human-caused climate change;
- Measurement of vulnerability of different groups, empirical validation of the measurements, and attribution of differences in vulnerability to proximate and underlying causes;
- Decision processes of different classes of actors for managing climate risks, the information needed to make good decisions, and how climate change information can be integrated into decision making processes;
- The role of institutions (rules, processes and organizations) in facilitating or limiting adaptation to climate hazards;
- Identification of effective strategies for enabling adaptation and lessons about how strategies that are successful in one context can be expanded in use or transferred to other contexts; and
- The benefits and costs of adaptation.

It is not unexpected that gaps remain. After all, despite global change research budgets of several billion dollars per year in the developed countries, there remain important gaps in knowledge, capacity and linkages in those countries as well. Making progress on filling these gaps is critically important for managing and reducing climate risks in the developing countries, and most particularly in the least developed countries. The AIACC project has demonstrated that a well designed project of relatively modest scale that invests in developing country science can yield substantial benefits. More projects of this type are needed. The remaining conclusions address lessons from AIACC for the design of effective projects for advancing knowledge, building scientific capacity and linking science, policy and stakeholder institutions.

11.2 Science Orientation, Merit Based Awards And Flexible Implementation

Implementation of the AIACC project was oriented toward advancing scientific knowledge and scientific capacity. An important contributor to success in achieving these objectives was the selection of climate change assessments based on scientific-merit review of proposals submitted in response to an open call that was widely advertised through scientific communities as well as through focal points of the GEF and UNFCCC. Broad requirements and criteria were set by the call, but applicants had considerable latitude to focus on sectors and issues and to propose approaches, methods and tools of their choosing. This allowed for a high degree of innovation and matching of project focus and design to the priorities, capabilities and interests of the applicants. The majority of successful proposals came from scientific institutions that partnered with institutions with complementary expertise, including government and stakeholder organizations as well as other scientific institutions. The result was a group of climate change assessments of high scientific quality in terms of objectives, methods and capabilities of the project teams.

There is a danger that in using a scientific-merit approach to selecting projects, institutions and countries in greatest need of scientific capacity development will not be able to compete with institutions and countries with stronger scientific capabilities. This danger was recognized from the outset and mitigating measures were put in place. Specifically, the Implementing Committee and Technical Committee gave weight in the review process to proposals from countries with low capacity that were basically sound in their objectives and general approach, that included appropriate types of institutions and participants, but for which the then existing capabilities of the proposal team were potentially lacking in some areas. A number of such proposals were selected and executed by the AIACC project. Providing appropriate technical support to these teams was demanding, but their ultimate performance demonstrated that the selections were wise.

Despite the effort to include assessments from countries with lower scientific capacity, it is true that, with only a few exceptions, countries with very low scientific capacity did not participate in the AIACC project. The most notable absence from the project is the lack of any climate change assessments for Central African countries. Very few proposals were received from these countries, and those that were received would likely not have been capable of successful execution within the context of the AIACC project. One reason for receiving few proposals from these countries is that the scientific networks are not well developed and so it is difficult for a request for proposals to reach the relevant institutions and individuals. Second, climate change assessments require teams of investigators from multiple disciplines, and assembling a multidisciplinary team requires institutional capacity that is often lacking. Finally, writing a proposal for a climate change assessment that has sound objectives and approach also requires capacity that can be lacking in the Least Developed Countries. A project like AIACC can succeed in these contexts, but would need to include an initial and intensive project development phase, as well as capacity building that is designed for the specific needs of science institutions in LDCs. A project development phase could assist elements of the scientific community of a Least Developed Country to assemble an appropriate team of institutions and experts and to undertake initial capacity building efforts to raise awareness of climate change issues and assessment methods.

11.3 Capacity Building

A comprehensive approach to capacity building was taken by the AIACC project. Learning-by-doing was the most important component. Climate change capacity building activities are much more effective when the participants are also substantively involved in the execution of a climate change assessment. Technical assistance, training and networking were important supplements. Efforts were made to utilize the expertise of developing country participants to assist with training and capacity transfers to their colleagues and this worked quite well. A substantial portion of the capacity building resulted from the cross-project learning and sharing of methods, expertise, data and experiences with stakeholder processes. The global training workshops were an efficient means for coming to a common understanding of the objectives and general approach of the AIACC project, to expose the assessment teams to some assessment methods and tools that were new to many, and to provide limited in-depth training in a few selected methods. But a significant number of participants had expectations that the training workshops would provide greater opportunities for in-depth, hands on training in specific tools that were of special interest to them. The training workshops were not good at providing this. This need was partly addressed by making small additional grants available to the teams, made possible by funding from USAID, that could be used for capacity building and/or stakeholder activities of their own choosing and design. This proved to be an effective approach and we recommend that it be applied in future projects.

The individual and institutional capacities built by AIACC show some signs of being sustainable as all the teams are continuing to engage in the climate change issue. A number of factors contribute to this sustainability. First, the project's regional climate change assessments were executed by scientific institutions that have long-term commitments to research, education, and training related to climate change hazards and therefore possess a strong self-interest to further invest in and use the capacities enhanced by the AIACC project. Second, individual capacity building and training efforts were targeted to early-career scientists. As they develop capabilities to excel in this field, it is expected that many will focus future research, assessment, and policy activities to address problems of climate change. Third, the success that AIACC has found in developing cross-institutional collaborations and engagement of participants with IPCC, MEA, IAAST, and the global change research programs has developed networks that will serve to keep the individuals and institutions that participated in AIACC engaged in climate assessment work.

However, despite these positive signs, the enhanced capacity yielded by the project is vulnerable. Some of the assessment teams have succeeded in securing resources to continue working together on the problems of climate change and adaptation, and this will help to sustain their capacity. But many more have not. Without new resources to fund new efforts, the institutions that participated will invest their energies in pursuing opportunities in areas other than climate change; they will lose persons with relevant knowledge and skills; and their relationships with other institutions working on climate change will weaken from disuse. Further investments are needed by projects similar to AIACC to nurture and sustain the capacity in developing countries for advancing knowledge about climate change risks and applying new knowledge to better management of the risks.

11.4 Management Approach

Execution of the project was aided by the soft-handed approach taken by UNEP as the implementing agency. UNEP allowed the executing agencies, START and TWAS, considerable discretion in managing the project and provided its guidance in a collaborative manner through discussions and decisions taken within the project Implementing Committee. The same approach was taken by START and TWAS with respect to the regional assessment teams, giving the developing country administering institutions and principal investigators discretion to decide how best to execute their activities within the scope of their grants. Guidance, assistance and oversight were provided by the AIACC project, but responsibility for managing the climate change assessments lay with the developing country institutions. We consider this approach to have been very effective and to have been successful in developing good working relationships and respect among all the participating institutions.

Execution of multiple climate change assessments under the umbrella of a larger project produced substantial synergistic benefits. As noted above, much of the capacity building resulted from the cross-project interactions. Executing a group of assessments together also made it possible for investigators from multiple projects of broadly similar design to compare results from across the projects and to identify and synthesize common lessons.

The number of climate change assessments executed, 24, is probably at the upper limit of what can be efficiently managed with the level of administrative and technical support services that were provided for the AIACC project. The tasks of monitoring performance, providing technical assistance and training, organizing workshops, reviewing outputs, and managing, synthesizing and communicating the enormous flow of information produced by 24 scientific projects were highly demanding. Successful execution was made possible by the dedicated assistance of the Technical Committee. Larger projects with more assessments would need to have greater staffing than did the AIACC project. Projects that include 6 to 12 climate change assessments are probably sufficient to provide significant cross-assessment synergistic benefits and be of a scale that can be managed without a large full time staff.

An important factor in the scientific success of the AIACC project is the high level of scientific expertise and dedication of the project Technical Committee. The Technical Committee was composed of well regarded and internationally known scientists and experts, including individuals from developing and developed countries, most of whom had been authors of the IPCC's 3rd Assessment Report. These individuals brought a great deal of knowledge and experience to the project that influenced to the better the objectives, design and implementation of the project. The Technical Committee members gave substantial amounts of their time to guide implementation of the project, assist individual climate change assessments, and to engage AIACC project participants in a wide range of international science activities. The AIACC experience demonstrates the importance of a highly knowledgeable, respected and dedicated Technical Committee to the success of a complex, multi-institutional, multi-sector, multi-disciplinary assessment project.

11.5 Balance Between Science And Policy

From the start of the AIACC project there has been a tension between advancing science and serving policy needs, particularly those of the UNCCC process. The tension was a healthy one that moved the project toward a stronger policy orientation than was incorporated into the original design of the project. Policy relevance and inclusion of participants from policy communities were important factors in the review and selection of climate change assessments. But the proposal for AIACC having come from the science community, and the selected climate change assessments being administered mostly by scientific institutions, created some hurdles for connecting to policy processes.

To address these hurdles, the importance of serving policy needs and engaging stakeholders from national climate change committees, relevant national agencies and stakeholders from at-risk groups was emphasized in the global kick-off meeting and training workshops held in the first year of the project. During implementation, each of the assessments was required to engage with the national communication process in their countries and strongly encouraged to engage with other stakeholders that could benefit from and apply results from the assessments to adapt to climate change. It was not always easy retrofitting stakeholder processes into assessments that did not include and budget for them from the beginning, or that did so in relatively minimal ways. The assessments were aided in this by allowing teams to revise work plans and reallocate budgets. In addition, the assessment teams were given additional supplemental grants to allow them to expand stakeholder activities. Linkages to international and national policy processes were reinforced by including representatives of these processes in the regional workshops organized by AIACC, by organizing side events at COPs, by involving AIACC participants in expert meetings of the UNFCCC and by sponsoring participation of AIACC investigators in policy meetings. Local stakeholders for each of the assessments were also invited to the regional workshops of AIACC, and each assessment held its own stakeholder workshops, focus groups and consultations.

For many of the local stakeholder groups, the issues of climate change and climate change adaptation did not initially resonate well with their concerns and priorities. But the issue of current climate hazards did resonate with most groups. The AIACC climate change assessments found that by linking climate change to current climate hazards, many stakeholder groups came to perceive climate change as highly relevant to their interests. Most groups recognize that there are serious deficits in how climate hazards are presently managed and came to appreciate the logic and importance of narrowing these deficits as a step toward adapting to climate change. This approach is one that worked well across the many different contexts of the AIACC assessments and is one that can be used to increase the relevance and utility of assessments to stakeholders.

The end result is that the AIACC climate change assessments did engage effectively with policy processes. All are involved in some way with national communication processes, some very intensively. All have stakeholders that they have served and who are using outputs of the assessments to further their understanding of climate change risks and adaptation options. To better facilitate these types of outcomes, future science-oriented projects similar to AIACC should incorporate activities for stakeholder participation in the initial design, work plan and budgets of each sub-project. The new CCAA program and ACCCA project are taking exactly this approach.

One caution is needed, however. A great deal more still needs to be done in developing countries to advance scientific knowledge about climate change vulnerability and adaptation and this requires further enhancement of scientific capacity in the developing world, both of institutions and people. Bilateral and multilateral assistance agencies that have in the past supported science in developing countries related to climate change and global environmental change are increasingly emphasizing "action research" that is focused on policy applications and delivering "on the ground benefits." This approach, while important and useful, allocates relatively small resources to expanding scientific knowledge and building scientific capacity. Meanwhile, science-funding agencies, while providing some support for science in developing countries, have generally considered the development assistance agencies to have the primary responsibility for this. There is a danger of a growing gap in funding for the underlying science and scientific capacity in developing countries that are essential for sustainable progress on reducing environmental and climate change threats. The International Group of Funding Agencies (IGFA) for global change research is aware of this gap and has initiated discussions with the development assistance community. But at present the prospects for adequate support of science capacity building do not look good.

Annex A: AIACC Outputs

Outputs of the AIACC project include papers and chapters in peer-reviewed journals and books, the on-line peer-reviewed *AIACC Working Papers* series, final reports of the regional climate change assessments, student theses, other non-peer reviewed papers and books, and on-line and CD training course materials.

Following is a listing of publications and other outputs of the project.

Peer Reviewed Publications

Peer-reviewed publications forthcoming in 2008

1. Leary, N., C. Conde, J. Kulkarni, A. Nyong and J. Pulhin, editors. 2008a. *Climate Change and Vulnerability*. Earthscan, London, UK. (A collection of papers from the AIACC regional assessments)
2. Leary, N., J. Adejwon, V. Barros, I. Burton, J. Kulkarni and R. Lasco, editors. 2008b. *Climate Change and Adaptation*. Earthscan, London, UK. (A collection of papers from the AIACC regional assessments)

Peer-reviewed publications in 2007

1. Amarakoon, D., D. Chadee, A. Chen, R. Rawlins and M. Taylor. 2007 (forthcoming). 'Dengue epidemics in the Caribbean – temperature indices to gauge the potential for onset of dengue.' *Mitigation and Adaptation Strategies for Global Change*. (AIACC Project No. SIS06).
2. Magrin, G O., M I Travasso, W E. Baethgen and R T. Boca. 2007. 'Improving applications in agriculture of ENSO-based seasonal rainfall forecasts considering Atlantic Ocean surface temperatures.' In M. Sivakumar and J. Hansen (eds*), Climate Prediction and Agriculture. Advances and Challenges*. Springer, Heidelberg, Germany. (AIACC Project No. LA27).
3. Olago, D., M. Marshall, S. Wandiga, M. Opondo, P. Yanda, R. Kangalawe, A. Githeko, T. Downs, A. Opere, R. Kabumbuli, E. Kirumira, L. Ogallo, P. Mugambi, E. Apindi, F. Githui, J. Kathuri, L. Olaka, R. Sigalla, R. Nanyunja, T. Baguma, and P. Achola. 2007. Climatic, socio-economic and health factors affecting human vulnerability to cholera in the Lake Victoria basin, East Africa. *Ambio*.36(1): 1-10. (AIACC Project No. AF91).
4. Osman-Elasha, B., E. Spanger-Siegfried, N. Goutbi, S. Zakieldin and A. Hanafi. 2007. 'Sustainable livelihood measures: lessons for climate change adaptation in arid regions of Africa.' *Annals of Arid Zone* 44(3&4):403-419. (AIACC Project No. AF14).
5. Peiris, T.S.G., J. Hansen, L. Zubair. 2007. Use of Seasonal Climate Information to Predict Coconut Production in Sri Lanka, *International Journal of Climatology* (in Press). (AIACC Project No. AS12).
6. Peiris, T.S.G., and J.D.J. Kularatne. 2007. 'Trends and changes in rainfall and temperature (1950-2001) in Hambantota.' Journal of the National Science Foundation of Sri Lanka (accepted for publication). (AIACC Project No. AS12).
7. Wijeratne, M.A., A. Aanadacumaraswamy, M.K.S.L.D Amarathunga, J. Ratnasiri, B.R.S.B. Basnayake and N. Kalra**.** 2007. Assessment of impact of climate change on productivity of tea (*Camellia sinensis* L.) plantations in Sri Lanka, *Journal of the National Science Foundation of Sri Lanka* (Accepted for publication). (AIACC Project No. AS12).
8. Wijeratne, M.A., J. Ratnasiri, and E.W.T.P. Premathunga. 2007. Effect of CO_2 fertilization on growth and yield of mature tea in the low country wet zone of Sri Lanka, *Journal of Plantations Crops* (Accepted for publication). (AIACC Project No. AS12).
9. Yin, Y. Y., P. Gong, and Y. H. Ding. Forthcoming 2007. Integrated assessments of vulnerabilities and adaptation to climate variability and change in western region of China. In SCOPE/START, *Changes in Human-Monsoon system of East Asia in the Context of Global Change*, Islands Press. (AIACC Project No. AS25)

Peer-reviewed publications in 2006

1. Adejuwon, J.O. 2006. Food crop production in Nigeria II: Potential effects of climate change. *Climate Research* 32(3):229-245. (AIACC Project No. AF23)
2. Adejuwon, J.O. and T. O. Odekunle. 2006. Variability and the severity of the “Little Dry Season” in southwestern Nigeria. *Journal of Climate,* 19(1): 483-493. (AIACC Project No AF23)
3. Adejuwon, J.O and O.O. Ogunkoya (eds). 2006. *Climate Change and Food Security in Nigeria*. Obafwmi Awolowo University Press, Ile-Ife 270 pp. (AIACC Project No. AF23)
4. Chadee, D. D., B. Shivnauth, S. C. Rawlins and A. A. Chen. 2006. Climate variability, mosquito indices and epidemiology of dengue fever in Trinidad (2002-2004): A prospective study. *Annals of Tropical Medicine and Parasitology* 100(6):1-9. (AIACC Project No. SIS06).
5. Mataki, M., K. Koshy and M. Lal. 2006. Baseline climatology of Viti-Levu (Fiji) and current climate trends. *Journal of Pacific Science*, 60 (1): 49-68 (AIACC Project No. SIS09).
6. Odekunle, T.O. 2006. ‘Determining rainy season onset and retreat over Nigeria from precipitation amount and number of rainy days, *Theoretical and Applied Climatology* 83:193-201.
7. Tadross, M.A., Gutowski W.J. Jr., Hewitson B.C., Jack C.J., New M. 2006. ‘MM5 simulations of interannual change and the diurnal cycle of southern African regional climate.’ *Theoretical and Applied Climatology*, 86, 63-80. (AIACC Project No. AF07).
8. Waidyarathne, K.P., T.S.G. Peiris and S. Samita. 2006. ‘Shift in onset of first inter-monsoon rain in coconut growing areas of Sri Lanka.’ *Journal of Tropical Agricultural Research* 18:1-12. (AIACC Project No. AS12).
9. Xu, Z. M., G. D. Cheng, A. H. Long, J. Loomis, Z. Q. Zhang and K. Hamamura. 2006. Evaluating the performance of different willingness to pay question formats for valuing environmental restoration in rural China. *Environment and Development Economics* 11(5):585-601. (AIACC Project No. AS25)
10. Yanda, P. Z., R. Y. M. Kangalawe and R. J. Sigalla. 2006. Climatic and socio-economic influences on malaria and cholera risks in the Lake Victoria region of Tanzania. *ICFAI Journal of Environmental Economics* IV(3):44-70. (AIACC Project No. AF91)

Peer-reviewed publications in 2005

1. Adejuwon, J.O. 2005. Food crop production in Nigeria I: Potential effects of climate change. *Climate Research,* 30(1): 53-60. (AIACC Project No. AF23)
2. Cavazos, T. and B. Hewitson. 2005. Performance of NCEP-NCAR reanalysis variables in statistical downscaling of daily precipitation. *Climate Research,* 28: 96-107. (AIACC Project No. AF07)
3. Conde, C. and K. Lonsdale. 2005. Engaging stakeholders in the adaptation process. In B. Lim and E. Spanger-Siegfried (Eds.), *Adaptation Policy Frameworks for Climate Change: Developing Strategies, Policies and Measures*, United Nations Development Programme. Cambridge University Press, 47-66. (AIACC Project No. LA29)
4. Del Ponte, E. M., J. M. C. Fernandes and C.R. Pierobom. 2005. Factors affecting density of Gibberella zeae inoculum. *Fitopatologia Brasileira*, 30(1): 55-60 (In Portuguese). (AIACC Project No. LA27)
5. Del Ponte, E. M., J. M. C. Fernandes and W. A. Pavan. 2005. Risk infection simulation model for Fusarium head blight of wheat. *Fitopatologia Brasileira,* 30(6): 634-642. (AIACC Project No. LA27)
6. Fenech, A., D. MacIver, H. Auld, B. Rong, and Y. Y. Yin (Eds.). 2005. *Climate Change: Building the Adaptive Capacity*. Environment Canada, Toronto, Ontario. 426 pp. (Multiple papers from AIACC Project No. AS25)
7. Hewitson, B. and R. Crane. 2005. Gridded area-averaged daily precipitation via conditional interpolation. *Journal of Climate,* 18: 41-57. (AIACC Project No. AF07)
8. Jenkins, G. S., A. T. Gaye, and B. Sylla. 2005. Late 20th century attribution of drying trends in the Sahel from the Regional Climate Model (RegCM3). *Geophysical Research Letters,* 32. (AIACC Project No. AF20)
9. Kamga, A. F., G. S. Jenkins, A. T. Gaye, A. Garba, A. Sarr, and A. Adedoyin. 2005. Evaluating the National Center for Atmospheric Research climate system model over West Africa: present-day and the 21st Century A1 Scenario. *Journal of Geophysical Research* 110:D03106. (AIACC Project No. AF20)
10. Lappo, S. S., E. Morozov, D. N. Severov, A. V. Sokov, A. A. Kluivitkin, and G. Nagy. 2005. Frontal mixing of river and sea waters in the Rio de la Plata. *Doklady Earth Sciences,* 401, No. 2: 226-228 (translated from *Doklady Akademii Nauk,* 400, No. 5: 690-692). (AIACC Project No. LA32)

11. Nagy, G., D. Severov, V. Pshennikov, M. Santos, J. Lagomarsino, K. Sans and E. Morozov. 2005. Rio de la Plata System: Relationship between river flow and frontal variability. Advances in Space Research, Elsevier. (AIACC Project No. LA32)
12. Payet R.A. 2005. Climate policy implications of the recent ENSO events in a small island context. In Pak Sum Low (Ed.), *Climate and Africa*, Cambridge University Press, 229-237. (AIACC Project No. SIS90)
13. Rawlins, S. C., A. Chen, J. M. Rawlins, D. D. Chadee and G. Legall. 2005. A knowledge, attitude and practices study of the issues of climate change and public health in two Caribbean countries. *West Indian Medical Journal,* 54 (Suppl 2): 78-79. (AIACC Project No. SIS06)
14. Sheppard C., D. Dixon, M. Gourlay, A. Sheppard and R. A. Payet. 2005. Coral mortality increases wave energy reaching shores protected by reef flats: Examples from the Seychelles, *Journal of Estuarine, Coastal and Shelf Science.* (AIACC Project No. SIS90)
15. Tadross, M.A., Hewitson B.C. and Usman M.T. 2005. 'The interannual variability of the onset of the maize growing season over South Africa and Zimbabwe.' *Journal of Climate*., 18(16), 3356-3372. (AIACC Project No. AF07).
16. Tadross, M.A., Jack C., and Hewitson B.C. 2005. 'On RCM-based projections of change in southern African summer climate.' *Geophysical Research Letters*, 32(23), L23713. (AIACC Project No. AF07).
17. Warrick, R., W. Ye, P. Kouwenhoven, J. E. Hay, and C. Cheatham. 2005. New development of the SimCLIM Model for simulating adaptation to risks arising from climate variability and change. In A. Zerger and R. M. Argent (Eds.), MODSIM 2005 International Congress on Modelling and Simulation. Modelling and Simulation Society of Australia and New Zealand. (AIACC Project No. SIS09)
18. Williams, P., L. Hannah, S. Andelman, G. F. Midgley, M. Araujo, G. Hughes, L. Manne, E. Martinez-Meyer and R. Pearson. 2005. Planning for climate change: Identifying minimum-dispersal corridors for the Cape Proteaceae. *Conservation Biology*, 19: 1063-1074. (AIACC Project No. AF04)
19. Xu, Z. M., G. D. Cheng, and G. Qiu. 2005. ImPACTS identity of sustainability assessment. *Acta Geographica Sinica,* 60(2): 198-208 (In Chinese with English Abstract). (AIACC Project No. AS25)

Peer-reviewed publications in 2004

1. Abou Hadid, A. F., M. Medany, S. A. Ouda, S. M. El-Marsafawy and H. Eid. 2004. Assessment of the impact, adaptation and vulnerability to climate change on wheat productivity using empirical modeling. *Egyptian Journal of Horticultural Science*. (AIACC Project No. AF90)
2. Adejuwon, J. 2004. Assessing the suitability of EPIC crop model for use in the study of impacts of climate change in West Africa. *Singapore J of Tropical Geography,* 24: 44-60. (AAICC Project No. AF23)
3. Adejuwon, J. and T. Odekunle. 2004. Skill assessment of the existing capacity for extended range weather forecasting in Nigeria. *International Journal of Climatology,* 24: 1249-1265. (AAICC Project No. AF23)
4. Callaway, J. M. 2004a. Adaptation benefits and costs: are they important in the global policy picture and how can we estimate them. *Global Environmental Change,* 14: 273-282. (AIACC Project No. AF47)
5. Callaway, J. M. 2004b. Chapter 4: The benefits and costs of adapting to climate variability and change. In *The benefits and costs of climate change policies: analytical and framework issues,* Paris: OECD Press, 111-158. (AIACC Project No. AF47)
6. Dragani, W. C. and S. I. Romero. 2004. Impact of a possible local wind change on the wave climate in the upper Río de la Plata. *International Journal of Climatology,* 24(9): 1149-1157. (AIACC Project No. LA26)
7. Escobar, G., W. Vargas and S. Bischoff. 2004. Wind tides in the Rio de la Plata estuary: meteorological conditions. *International Journal of Climatology* 24(9): 1159-1169. (AIACC Project No. LA26)
8. Kang, E. S., G. D. Cheng, K. C. Song, B. W. Jing, X. D. Liu and J. Y. Wang. 2004. Simulation study of energy and water balance in soil-vegetation-atmospheric system in the Heihe mountainous area of Hexi Corridor. *Science in China D: Earth Sciences,* 34(6): 544-551 (In Chinese). (AIACC Project No. AS25)

9. Mansour, M., R. Mougou et A. Mougou. 2004. Effet de trois doses d'irrigation et de deux dates de plantation sur le comportement de la tomate de saison. *Revue de l'Institut National Agronomique de Tunis*, 9(2). (AIACC Project No. AF90)
10. Mansour, M., T. Oueslati, R. Mougou, et A. Mougou. 2004. Etude du development de deux varietes d'artichaut: Violet d'Hyeres et Blanc Oranais. *Revue de l'Institut National Agronomique de Tunis*, 9(2). (AIACC Project No. AF90)
11. Odekunle, T. 2004. Rainfall and the length of the growing season in Nigeria. *Int'l J of Climatology,* 24: 467-479. (AAICC Project No. AF23)
12. Odekunle, T.O., E. E. Balogun, and O. O. Ogunkoya. 2004. On the prediction of rainfall onset and retreat dates in Nigeria. *Theoretical and Applied Climatology*, 1-12. (AIACC Project No. AF23)
13. Piyasiri, C. H., T. S. G**.** Peiris and S. Samita. (2004). Change in rainfall and temperature of Low Country Wet Intermediate (IL1) region of Sri Lanka. *Tropical Agricultural Research,* 16: 271-280. (AIACC Project No. AS12)
14. Rawlins, S. C., A. Chen, M. Ivey, D. Amarkoon and K. Polson. 2004. The impact of climate change /variation events on the occurrence of dengue fever in parts of the Caribbean: a retrospective study for the period 1980 - 2002. *West Indian Med. Journal* 53(Suppl. 2): 54. (AIACC Project No. SIS06)
15. Rivarola, A., R. Seiler y M. Vinocur. 2003/2004. Vulnerabilidad y adaptación de los productores agropecuarios al cambio y a la variabilidad climática: el uso de la información agrometeorológica**.** *Revista Reflexiones Geograficas* 11: 109-120. ISSN: 0328-0004 (Spanish). (AIACC Project No. LA29)
16. Yin, Y. Y. 2004. Methods to link climate impacts and regional sustainability. *J. of Environmental Informatics* 2(1): 1-10 (AIACC Project No. AS25)
17. Zubair, L. 2004. Towards developing weather and climate prediction for Sri Lanka. *Journal of the Institute of Engineers*, Sri Lanka, XXXVII(2): 53-58. (AIACC Project No. AS12)

Peer-reviewed publications in 2003

1. Camilloni, I. A. and V. R. Barros. 2003. Extreme discharge events in the Parana River and their climate forcing*. J of Hydrology,* 278: 94-106. (AIACC Project No. LA26)
2. Dube, O. P. 2003. Impacts of climate change, vulnerability and adaptation options: Exploring the case for Botswana through southern Africa, A review. The Journal of Botswana Society. *Botswana notes and records,* 35: 147-168. (AIACC Project No. AF42)
3. Eakin, H. 2003. The social vulnerability of irrigated vegetable farming households in central Puebla. *Journal of Environment & Development*, 12(4): 414-429. (AIACC Project No. LA29)
4. Hewitson, B. 2003. Developing perturbations for climate change impact assessments. *EOS,* 84(35): 337-341. (AIACC Project No. AF04).
5. Rivarola A. del V., M. G. Vinocur y R. A. Seiler. 2002/03. Uso y demanda de información agrometeorológica en el sector agropecuario del centro de Argentina. *Revista Argentina de Agrometeorología* (RADA), **2**(2): 143-149. ISSN 1666-017X (Spanish). (AIACC Project No. LA29)
6. Seiler, R. A. y L. Bressán. 2002/03. Evaluación y seguimiento de las condiciones de humedad del suelo en Córdoba mediante el indice estandarizado de precipitación. *Revista Argentina de Agrometeorología* (RADA) **2**(2): 187-192. ISSN 1666-017X (Spanish). (AIACC Project No. LA29)
7. van Jaarsveld, A. S., G. F. Midgley, R. J. Scholes, and B. Reyers. 2003. Conservation management in a changing world. In N. Allsopp, A. R. Palmer, S. J. Milton, K. P. Kirkman, G. I. H. Kerley, C. R. Hurt, and C. J. Brown (Eds.), *Proceedings of the VIIth International Rangelands Congress*, 26 July – 1 August 2003, Durban, South Africa. (AIACC Project No. AF04)

AIACC Working Papers

AIACC Working Papers, published on-line by AIACC, is a series of papers written by participants in the AIACC project. Papers published in *AIACC Working Papers* have been peer reviewed and accepted for publication in the on-line series as being (i) fundamentally sound in their methods and implementation, (ii) informative about the methods and/or findings of new research, and (iii) clearly written for a broad, multi-disciplinary audience. The purpose of the series is to circulate results and descriptions of methodologies from the AIACC project and elicit feedback to the authors.

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- Working Paper No. 1: Conservation management in a changing world. Albert S. van Jaarsveld, Guy F. Midgley, Robert J. Scholes and Belinda Reyers. December 2003. (AIACC Project No. AF04)
- Working Paper No. 2: Extreme discharge events in the Paraná River and their climate forcing. Inés A. Camilloni and Vicente R. Barros. December 2003. (AIACC Project No. LA26)
- Working Paper No. 3: Developing perturbations for climate change impact assessments. Bruce Hewitson. December 2003. (AIACC Project No. AF07)
- Working Paper No. 4: Trends in river and lake ice in Mongolia. Batima Punsalmaa, Batnasan Nyamsuren and Bolormaa Buyndalai. May 2004. (AIACC Project No. AS06)
- Working Paper No. 5: Assessing the suitability of the EPIC crop model for use in the study of impacts of climate variability and climate change in West Africa. James O. Adejuwon. May 2004. (AIACC Project No. AF23)
- Working Paper No. 6: Skill assessment of the existing capacity for extended range weather forecasting in Nigeria. James O. Adejuwon and Theophilus O. Odekunle. May 2004. (AIACC Project No. AF23)
- Working Paper No. 7: Impact of a possible local wind change on the wave climate in the upper Rio de la Plata. Walter C. Dragani and Silvia I. Romero. July 2004. (AIACC Project No. LA26)
- Working Paper No. 8: Wind tides in the Rio de la Plata estuary: Meteorological conditions. Gustavo Escobar, Walter Vargas and Susana Bishcoff. June 2005. (AIACC Project No. LA26)
- Working Paper No. 9: Rainfall and the length of the growing season in Nigeria. T.O. Odekunle. June 2005. (AIACC Project No. AF23)
- Working Paper No. 10: Carbon budgets of terrestrial ecosystems in the Pantabangan-Carranglan watershed. Rodel Lasco et al June 2005. (AIACC Project No. AS21)
- Working Paper No. 11: A collaborative effort towards developing capacity for operational fire monitoring and management systems in Southern Africa. Pauline Dube. June 2005. (AIACC Project No. AF42)
- Working Paper No. 12: Climatic and socio-economic influences on malaria and cholera risks in the Lake Victoria region of Tanzania. Pius Yanda et al June 2005. (AIACC Project No. AF91)
- Working Paper No. 13: Observed climate change in Mongolia. Punsalmaa Batima et al June 2005. (AIACC Project No. AS06)
- Working Paper No. 14. Performance of NCEP-NCAR reanalysis variables in statistical downscaling of daily precipitation. T. Cavazos and B. Hewitson. July 2005. (AIACC Project No. AF07)
- Working Paper No. 15: Gridded area-averaged daily precipitation via conditional interpolation. B. Hewitson and R. Crane. July 2005. (AIACC Project No. AF07)
- Working Paper No. 16: On the prediction of rainfall onset and retreat dates in Nigeria. T.O. Odekunle, E.E. Balogun, and O.O. Ogunkoya. August 2005. (AIACC Project No. AF23)
- Working Paper No. 17: Sustainable livelihood approach for assessing community resilience to climate change: case studies from Sudan. B. Osman-Elasha, N.G. Elhassan, H. Ahmed, and S. Zakieldin. August 2005. (AIACC Project No. AF14)
- Working Paper No. 18: Methodological framework: an internal scoping report of the project Strategies for Increasing Human Resilience in Sudan: Lessons for Climate Change Adaptation in North and East Africa. E. Spanger-Siegfried, B. Dougherty, N. G. El Hassan, and B. Osman-Elasha. August 2005. (AIACC Project No. AF14)
- Working Paper No. 19: Social methods for assessing agricultural producers' vulnerability to climate variability and change based on the notion of sustainability. M. B. Wehbe, R. A. Seiler, M. G. Vinocur, H. Eakin, C. Santos, and H. M. Civitaresi. August 2005. (AIACC Project No. LA29)
- Working Paper No. 20: Climate variability and change: implications for household food security. G. Ziervogel, A. Nyong, B. Osman-Elasha, C. Conde, S. Cortes, and T. Downing. January 2006 (AIACC Project Nos. AF14, AF92, LA29)
- Working Paper No. 21: For whom the bell tolls, vulnerabilities in a changing climate. N. Leary and others. January 2006. (A synthesis from the AIACC Project)
- Working Paper No. 22: Assessing vulnerability to climate variability and change in estuarine waters and coastal fisheries of the Rio de la Plata. G. J. Nagy and others. January 2006. (AIACC Project No. LA32)
- Working Paper No. 23: A plan of action to support climate change adaptation through scientific capacity, knowledge and research. N. Leary and others. January 2006.

- Working Paper No. 24: Vulnerability of Southern African fauna and flora to climate change. G. P. von Maltitz and R. J. Scholes. March 2006. (AIACC Project No. AF04)
- Working Paper No. 25: Vulnerability to climate induced highland malaria in East Africa. S. O. Wandiga and others. March 2006. (AIACC Project No. AF91)
- Working Paper No. 26: Vulnerability to floods in the metropolitan region of Buenos Aires under future climate change. V. Barros and others. April 2006. (AIACC Project No. LA26)
- Working Paper No. 27: Vulnerability to Dengue fever in Jamaica. C. Heslop-Thomas and others. May 2006. (AIACC Project No. SIS06)
- Working Paper No. 28: Adaptation measures for maize and soybean in Southeastern South America. M. I. Travasso and others. June 2006. (AIACC Project No. LA27)
- Working Paper No. 29: A comparison of the social vulnerability of grain farmers in Mexico and Argentina. H. Eakin and others. June 2006. (AIACC Project No. LA29)
- Working Paper No. 30: Climatic threat spaces as a tool to assess current and future climate risks: Case studies in Mexico and Argentina. C. Conde and others. June 2006. (AIACC Project No. LA29)
- Working Paper No. 31: The Berg river dynamic spatial equilibrium model: A new tool for assessing the benefits and costs of alternatives for coping with water demand growth, climate variability, and climate change in the western Cape. J. Callaway and others. June 2006. (AIACC Project No. AF47)
- Working Paper No. 32: Tradeoff analysis of adaptation strategies for natural resources, water resources, and local institutions in the Philippines. R. D. Lasco and others. June 2006. (AIACC Project No. AS21)
- Working Paper No. 33: Adapting to dengue risk – what to do?. M. A. Taylor and others. June 2006. (AIACC Project No. SIS06)
- Working Paper No. 34: Implementing climate change adaptation in the Pacific islands: Adapting to present climate variability and extreme weather events in Navua (Fiji). M. Mataki and others. June 2006. (AIACC Project No. SIS09)
- Working Paper No. 35: Adapting conservation strategies to accommodate impacts of climate change in southern Africa. G. P. von Maltitz and others. August 2006. (AIACC Project No. AF04).
- Working Paper No. 36: Adaptive Capacity for Responding to Climate Variability and Change in Estuarine Fisheries of the Rio de la Plata. G.J. Nagy and others. August 2006. (AIACC Project No. LA32).
- Working Paper No. 37: Making Economic Sense of Adaptation in Upland Cereal Production Systems in The Gambia. M. Njie and others. August 2006. (AIACC Project No. AF47)
- Working Paper No. 38: Adaptation to Climate Trends: Lessons From the Argentine Experience. V. Barros. September 2006. (AIACC Project No. LA26).
- Workng Paper No. 39: Local Perspectives on Adaptation to Climate Change: Lessons From Mexico and Argentina. M. Wehbe and others. September 2006. (AIACC Project No. LA29)
- Working Paper No. 40: Climate risks and rice farming in the lower Mekong River countries. S. Chinvanno and others. October 2006. (AIACC Project No. AS07).
- Working Paper No. 41: Evaluation of Adaptation Measures for Livestock Sector in Mongolia. P. Batima and others. October 2006. (AIACC Project No. AS06).
- Working Paper No. 42: Adaptation strategies to increase human resilience against climate variability and change: Lessons from the arid regions of Sudan. B. Osman-Elasha and others. October 2006. (AIACC Project No. AF14).
- Working Paper No. 43: Adaptation to Climate/Variability-Induced Highland Malaria and Cholera in the Lake Victoria Region. P. Yanda and others. October 2006. (AIACC Project No. AF91).
- Working Paper No. 44: Vulnerability of Communities to Climate Variability and Extreames: The Pantabangan-Carranglan Watershed in the Philippines. J. Pulhin and others. (AIACC Project No. AS21).
- Working Paper No. 45: Economic Value of Climate Variability on Coconut Production in Sri Lanka. Fernando, M.T.N., L. Zubair, T. S. G. Peiris, C. S. Ranasinghe and J. Ratnasiri. March 2007. (AIACC Project No. AS12).
- Working Paper No. 46: ‘Extended-range weather forecasting in Sub-Saharan West Africa: assessing a potential tool for adapting food production to climate variability and climate change. Adejuwon, J.O., T.O. Odekunle and M.O. Omotayo. March 2007. (AIACC Project No. AF23).

Other Publications, Not Peer Reviewed

1. Arntzen, J., O. P. Dube and M. Muchero. 2004. Global environmental change and food provision in Southern Africa: explorations for a possible Gecafs research project in Southern Africa. http://gecafs.org/outputs/. (AIACC Project No. AF42)
2. Baethgen, W. E., H. Meinke and A. Gimenez. 2004. Adaptation of agricultural production systems to climate variability and climate change: lessons learned and proposed research approach. In *Insights and Tools for Adaptation: Learning from Climate Variability*, NOAA-OGP, Washington, D.C. (AIACC Project No. LA27)
3. Baethgen, W. E and A. Gimenez. 2004. 2004. La variabilidad climática, el cambio del clima y el sector agropecuaio. Serie Actividades de Difusion, INIA, June . (AIACC Project No. LA27)
4. Barros, V., A. Menéndez y G. J. Nagy (Eds.). 2005. El cambio climático en el Río de la Plata. Publicación CIMA-UBA, Buenos Aires, 200pp. (In Spanish. Collection of 19 papers from AIACC Projects LA26 and LA32)
5. Barros, V. and others. 2005. El cambio climático y la costa del Río de La Plata (The Cimate Change and the Coast of the Plata River). *Fundación Ciudad,* 42 pp. (AIACC Project No. LA26)
6. Basnayake, B. R. S. B. and J. C.Vithanage. 2004. Rainfall change scenarios for Sri Lanka under the anticipated climate change. In *Proceeding of the International Conference on Sustainable Water Management in the Changing Environment of Monsoon Region*, 1-8, Colombo, Sri Lanka, November 17 - 19. (AIACC Project No. AS12)
7. Basnayake, B. R. S. B. and J. C.Vithanage. 2004, Spatial climatologies of rainfall and temperature for Sri Lanka with terrain dependency features. In *Proceedings of the First National Symposium on Geo - Informatics, Geo- informatics society of Sri Lanka*, University of Peradeniya, Sri Lanka, July 30. (AIACC Project No. AS12)
8. Basnayake, B. R. S. B. and J. C. Vithanage. 2004. Impacts and adaptation of climate change with emphasis on downscaling of future climate change scenarios as an impact assessment tool - A Sri Lanka perspective. In *Proceedings of the Second International Conference on Climate Change Impacts Assessment (SICCIA)*, Grainau, Germany, June 28 - July 2. (AIACC Project No. AS12)
9. Batima, P. and B. Myagmarjav (Eds.). 2005. The potential impact of climate change and V&A assessment for the livestock sector in Mongolia: *Climate change and its trends*, ISBN: 99929-0-615-4 (In Mongolian). (AIACC Project No. AS06)
10. Batima, P. and B. Bayasgalan (Eds.). 2005. The potential impact of climate change and V&A assessment for the livestock sector in Mongolia: *Climate change impacts*, ISBN: 99929-0-614-6 (In Mongolian). (AIACC Project No. AS06)
11. Batima, P. (Ed.). 2005. The potential impact of climate change and V&A assessment for the livestock sector in Mongolia: In *Vulnerability to climate change*, ISBN: 99929-0-616-2 (In Mongolian). (AIACC Project No. AS06)
12. Batima, P. and D. Tserendorj (Eds.). 2005. The potential impact of climate change and V&A assessment for the livestock sector in Mongolia: In *Adaptation to climate change*, ISBN: 99929-0-613-8 (In Mongolian). (AIACC Project No. AS06)
13. Batima, P. and others. 2005. The potential impact of climate change and V&A assessment for the Livestock Sector in Mongolia: Executive summary, ISBN: 99929-0-613-X. (AIACC Project No. AS06)
14. Batima, P and others. 2005. The potential impact of climate change and V&A assessment for the Livestock Sector in Mongolia: Recommendation for policy makers, ISBN: 99929-0-617-0 (In Mongolian). (AIACC Project No. AS06)
15. Batima, P. and others. 2004. *The Freshwater Systems of Western Mongolia's Great Lakes Basin: Opportunities and Challenges in the Face of Climate Change*. WWF Mongolia Programme office. (AIACC Project No. AS06).
16. Batima, P. 2003. Climate change: pasture and livestock, pp.119 (In Mongolian), ISBN: 99929-0-193-4. (AIACC Project No. AS06)
17. Boer, R., Perdinan, and A. Faqih. 2004. The use of Climatic Data Generator to cope with daily climatic data scarcity in simulation studies. *Proceeding of the 4th International Crop Science Congress* in Brisbane, October. (AIACC Project No. AS21)

18. Callaway, J. M. 2003. Adaptation benefits and costs – measurement and policy issues. OECD Workshop on the Benefits of Climate Policy: Improving Information for Policy Makers. OECD, ENV/EPOC/GSP(2003)10/FINAL. (AIACC Project No. AF07)
19. Centro Nacional de Cartografia e Teledeteccao. 2004. Mapping of flood affected areas. special report to the Ministerio da Agricultura e Desenvolvimento Rural, Republica de Moczambique. (AIACC Project No. AF38)
20. Cesar, H., V. Beukering, R.A, Payet, and E. Grandcourt. 2004. Evaluation of the socio-economic impacts of marine ecosystem degradation in the Seychelles. Cesar Environmental Economics Consulting, Netherlands, 96 pp. (Resident surveys supported by AIACC SIS90 project).
21. Chen, A. A., D. D. Chadee and S. C. Rawlins (eds). 2006. *Climate Change Impact on Dengue - The Caribbean Experience*. Climate Studies Group, Department of Physics, University of the West Indies, Mona, Jamaica. (AIACC Project No. SIS06).
22. Conde, C. 2004. Cambio climático en México (Climate Change in México). *La Ciencia de Boleto*. Gobierno del Distrito Federal, Coordinación de la Investigación Científica, UNAM, 15 pp. publicado, por repartirse en el 2005. (*This will be a free book, that will be distributed in the Mexico City subway in October, 2005, paid for by the government of the city*).
23. Conde, C., R. M. Ferrer, C. Gay, R. Araujo. 2004. Impactos del cambio climático en la agricultura en México. En Martínez, J. y A. Fernández (compiladores), *Cambio Climático: Una Visión desde México,* 227-238. (AIACC Project No. LA29)
24. Conde, C. and H. Eakin. 2003. Adaptation to climatic variability and change in Tlaxcala, Mexico. 2003. In J. Smith, R. Klein and S- Huq (Eds.), *Climate Change, Adaptive Capacity and Development*. Imperial College Press , London. 241-259. (AIACC Project No. LA29)
25. Cunha, G. R. da (Ed). 2004. *Lidando com riscos climaticos: clima, sociedade e agricultura*. (Coping with climatic risks: climate, society and agriculture). Passo Fundo: Embrapa Trigo, 400 p. (In Portuguese). (AIACC Project No. LA27)
26. Dube, O. P. 2005. Climate change in Southern Africa: Implications for the agricultural systems of Botswana. *Proceedings of the Botswana Agricultural Research Information Network* (BARIN). National Veterinary Laboratory, Gaborone. (AIACC Project No. AF42)
27. Fernandes, J. M. C1., E. M. Del Ponte, W. Pavan and Cunha, G. R. 2005. Web-based system to true-forecast disease epidemics – case study for Fusarium Head Blight of wheat. *Proceedings of the II International Workshop on climatic prediction and agriculture: Advances and Challenges*. Switzerland, May 11 to 13th. (AIACC Project No. LA27)
28. Gay, C., F. Estrada, C. Conde and H. Eakin. 2004. Impactos potenciales del cambio climático en la agricultura: escenarios de producción de café para el 2050 en Veracruz, México. En García Cordón et al (editores), *El Clima, entre el Mar y la Montaña*, 651-660. (AIACC Project No. LA29)
29. Giménez, A. J. P. Castaño, L. Olivera, J. Furest, W. E. Baethgen, D. L. Martino and R. Romero. 2004. Evidencias de cambio climatico en Uruguay. INIA, Uruguay, Ago-2004. (AIACC Project No. LA27)
30. Giménez, A. J. P. Castaño, L. Olivera, J. Furest, W. E. Baethgen, D. L. Martino and R. Romero. 2004. El clima, la producción agropecuaria y la toma de decisiones. *Revista Plan Agropecuario*.112:34-37. (AIACC Project No. LA27)
31. Hewitson, B. C., R. G. Crane and M. A. Tadross. (Forthcoming). Regional climate scenarios for impact assessment. In Otter, L., I. Niang-Diop and D. Olago (Eds.), *START Global Change and Africa: A Synthesis*. (AIACC Project No. AF04)
32. Kularatne, J. D. J. S., T. S. G. Peiris and D. T. Mathes. 2004. Long-term climate variability in Hambantota, 71. In B. M. de Silva and N. Mukhopadhyay (Eds.). *Proceedings of the International Sri Lankan Statistical Conference*, December 28-30 , Post Graduate Institute of Science, University of Peradeniya, Sri Lanka. (AIACC Project No. AS12)
33. Magrin G. O. 2005. Climatic change and the agricultural sector in South East South America. In *Proceedings of the II Regional Conference on Global Change: South America*, November 6 -10, Sao Paulo, Brasil. (AIACC Project No. LA27)
34. Magrin, G. O., M. I. Travasso, W. E. Baethgen and R. T. Boca. 2005. Improving applications in agriculture of ENSO-based seasonal rainfall forecasts considering Atlantic Ocean surface temperatures. CLIMAG 2005. (AIACC Project No. LA27)
35. Magrin, G. O., M. I. Travasso y G. R. Rodríguez. 2005. La agricultura ante el cambio climático**.** *Revista CREA*, Año XXXV, Número 291. (AIACC Project No. LA27)

36. Magrin, G. O., G. Rodriguez and M. I. Travasso. 2004. *Análisis de la precipitaciones ocurridas durante 1923-2000 en la región pampeana.* CD ROM, INTA-Instituto de Clima y Agua, 1712 Castelar, Argentina. (AIACC Project No. LA27)
37. Meinke, H., S. M. Howden, W. E. Baethgen, G. L. Hammer, R. Selvaraju and R. C. Stone. 2004. Can climate knowledge lead to better rural policies and risk management practices? In *Insights and Tools for Adaptation: Learning from Climate Variability*, NOAA-OGP, Washington, D.C. (AIACC Project No. LA27)
38. Mellouli, H. J., H. Askri and R. Mougou**.** 2002. Drip and surface irrigation water use efficiency of tomato crop using nuclear techniques. *Sixth Arab Conference on the Peaceful Uses of Atomic Energy*. Egypt 2002. (AIACC Project No. AF90)
39. Mohsen,M., R. Mougou and J. Marco. 2007. 'Les scénarios climatiques, un outil d'aide à la décision.' In the 13th seminar proceedings of the Institute for Research and High Schooling (IRESA), Tunisia (forthcoming). (AIACC Project No. AF90)
40. Mougou, R., **S.** Rejeb and F. Lebdi. 2002. The role of Tunisian - gender issues- in water resources management and irrigated agriculture. The First Regional Conference on Perspectives of Arab Water Cooperation: Challenges, Constraints and Opportunities, Workshop on Gender and Water Management in the Mediterranean. Published in the Acts of the workshop. (AIACC Project No. AF90)
41. Mougou,R., M. Mansour, A. Iglesias, R. Zitouna and A. Battaglini. 2007. 'Climate change and agriculture vulnerability: rainfed wheat in the Kairouan region, Tunisia.' In B. Hare, A. Battaglini, C. Jaeger and W. Cramer (eds), *Climate Impact Hotspots : Key Vulnerable Regions and Climate Change*. ECF, forthcoming. (AIACC Project No. AF90).
42. Nagy, G. J., K. Sans, J. Lagomarsino, and E. Andre. 2004. Estado trofico y cargas de los afluentes al Rio de la Plata y Oceano Atlantico. Technical Report, Facultad de Ciencias, Universidad de la Republica, Uruguay. (AIACC Project No. LA32)
43. Parida, B. P., D. B. Moalafhi and P. K. Kenabatho. 2003. Effect of urbanization on Runoff Coefficient - A case study of Notwane Catchment in Botswana. In *Proceedings of the International Conference on Water and Environment*, Bhopal, Vol. Watershed Hydrology: 123-131,Allied Publishers, India. (AIACC Project No. AF42)
44. Parida, B. P., D. B. Moalafhi and O. P. Dube. 2005. Estimation of likely impact of climate variability on runoff coefficients from Limpopo Basin using Artificial Neural Network (ANN). In *Proceedings of International Conference on Monitoring, Prediction and Mitigation of Water-Related Disasters*, Japan, 443 - 449. (AIACC Project No. AF42)
45. Parida, B. P. and E. Segosebe. 2005. Strategies for water security through water demand management. In *Proceedings of the International Conference on Crisis Management in Water & Environment*, July 15-16, Science City, Kolkatta (India), Vol. 1: 187-190. (AIACC Project No. AF42)
46. Peiris, T. S. G. (2004). Forecasting coconut production: issues, approaches, and challenges. In T. S. G. Peiris and C. S. Ranasinghe (Eds.)*, Proceedings of the International Conference of Coconut Research Institute of Sri Lanka – Part I* (Review papers and guest presentations), 111 – 147, The Coconut Research Institute of Sri Lanka, Lunuwila 61150, Sri Lanka. (AIACC Project No. AS12)
47. Peiris, T. S. G. (2002). Effect of temporal scale aggregation on climate change studies. In *Proceeding of the International Workshop on Regional Integrated Assessment of Climate Impacts*, September 16-20 , Castelvecchio Pascoli, Italy. (AIACC Project No. AS12)
48. Peiris, T.S.G., L. Zubair and C.H. Piyasiri. 2004. Forecasting national coconut production – A novel approach. In B. M. de Silva and N. Mukhopadhyay (Eds.), *Proceedings of the International Sri Lankan Statistical Conference*, December 28-30 , Post Graduate Institute of Science, University of Peradeniya, Sri Lanka. (AIACC Project No. AS12)
49. Piyasiri, C. H., T. S. G. Peiris and S. Samita. 2004. Empirical prediction of maximum and minimum air temperature in Sri Lanka. In B. M. de Silva and N. Mukhopadhyay (Eds.), *Proceedings of the International Statistical Conference: Visions of futuristic methodologies*, 371-379, December 28-30, Postgraduate Institute of Science, University of Peradeniya, Sri Lanka. (AIACC Project No. AS12)
50. Scholes, R. J., G. von Maltitz, M. de Wit, G. O. Hughes, G. Midgley, and B. Erasmus. 2004. Helping biodiversity adapt to climate change. *SciDevNetwork*. (AIACC Project No. AF04)
51. Van Jaarsveld, A. S., G. F. Midgeley, R. J. Scholes, and B. Reyers. 2003. Conservation management in a changing world. In N. Allsopp, A. R. Palmer, S. J. Milton, K. P. Kirkman, G. I. H. Kerley, C. R. Hurt, and C. J. Brown (Eds.), Proceedings of the VIIth International Rangelands Congress, July 26 – August 1, Durban, South Africa. (AIACC Project No. AF04)

52. Yin, Y. Y. 2004. A comprehensive assessment of vulnerability and adaptation to climate change in western areas of China. *World Environment* 3:23-25. (In Chinese). (AIACC Project No. AS25)
53. Yin, Y. Y. and G. Wang. 2004. *Global Climate Change Impact Assessment: Methods and Applications.* High Education Press, Beijing, China. (in Chinese). (AIACC Project No. AS25)
54. Zubair, L., U. Tennakoon and M. Siriwardhana. (2004). Climate Change Assessments for Sri Lanka from Quality Evaluated Data, In *Proceedings of International Conference on Sustainable Water Resources Management in the Changing Environment of the Monsoon Region*, November 17 - 19, United Nations University, Colombo, Sri Lanka. (AIACC Project No. AS12)

Student Theses Supported by AIACC

1. Boulidam, S. 2005. Vulnerability and adaptation of rainfed rice farmers to impact of climate variability in Lahakhok, Sebangnuane Tai, Dong Khanphou, and Koudhi Villages of Songkhone District, Savannakhet Provinve, Lao PDR. M. Sc. Thesis (Natural Resource Management), Mahidol University, Thailand, 97 pp. ISBN 974-04-5997-8. (AIACC Project No. AS07)
2. Conde, C. 2003. Climate change and climate variability: two study cases in Mexico. PhD Thesis, Earth Sciences, UNAM. 222 pp (in Spanish). (AIACC Project No. LA29)
3. Crossbourne, R. 2006. Developing a Caribbean Climate Interactive Database (CCID), M. Phil., University of the West Indies (AIACC Project No. SIS06)
4. Dabezies, M.J. 2005. Influencia del evento El Niño sobre la biomasa fitoplanctónica de la Bahía de Montevideo. Tesis de Licenciatura en Biología, Opción Oceanografía, Departamento de Ecología, Facultad de Ciencias, UdelaR. (AIACC Project No. LA32)
5. De Los Santos, M. 2005. Dinámica de frentes del Río de la Plata. Tesis de Licenciatura en Biología, Opción Oceanografía, Departamento de Ecología, Facultad de Ciencias, UdelaR. (AIACC Project No. LA32)
6. Drew, G. 2004. Modelling vegetation dynamics and their feedbacks over Southern Africa in response to climate change forcing. PhD Dissertation, University of Cape Town, South Africa. (AIACC Project No. AF07)
7. Erdenetuya, M. 2004. Remote sensing methodology and technology for pasture monitoring. Ph.D. Dissertation, Mongolian National University, Mongolia (AIACC Project No. AS06)
8. Flordeliz, A. 2004. Institutional impacts and adaptation strategies to climate variability and extremes in Pantabangan-Carranglan watershed. BS Thesis, College of Forestry and Natural Resources, University of the Philippines Los Baños, Philippines. (AIACC Project No. AS21)
9. Gichangi, K. 2004. Institutional and policy framework impact on vulnerability and adaptation capacity to climate change in eastern Botswana. M.Sc. Dissertation, University of Botswana, Gaborone. (AIACC Project No. AF42)
10. Heslop-Thomas, C. 2005. Vulnerability to dengue fever in Jamaica. M.Phil., University of the West Indies (AIACC Project No. SIS06)
11. Kabumbuli, R. 2006. Conflict dynamics in environmental resource management and use in Uganda: A study of Murchison Bay wetlands, Kampala. PhD Thesis, Makerere University. 250 pp (AIACC Project No. AF91)
12. Kgaodi, D. 2005. Effect of climate variability on runoff : A case study of Kgatleng District in the Limpopo Basin of Botswana. M.Sc. Dissertation, University of Botswana, Gaborone. (AIACC Project No. AF42)
13. Magagane, M. 2004. The role of climatic factors on the availability of Phane caterpillars in eastern Botswana. Undergraduate Dissertation, University of Botswana, Gaborone. (AIACC Project No. AF42)
14. Mdoka, M. 2005. Climatic trends and soil mositure feedbacks over Zimbabwe. MSc Dissertation, University of Cape Town, South Africa. (AIACC Project No. AF07)
15. Maiketso, S. 2004. Ecotourism as an alternative source of livelihood for the communities of the Greater Limpopo-Motloutse area in Eastern Botswana: Case studies of Mathathane, Makadibeng and Motlhababaneng. M.Sc. Dissertation, University of Botswana, Gaborone. (AIACC Project No. AF42)
16. Odekunle TO. 2003. Rainfall predictability in Southwestern Nigeria. PhD Thesis, Obafemi Awolowo University, Ile-Ife. Nigeria. (AIACC Project No. AF23)

17. Odeyemi, Y. 2005. An assessment of the impact of the changing physical environment on some aspects of human security in Southwestern Nigeria. PhD Thesis, Obafemi Awolowo University, Ile-Ife, Nigeria 249 pp (AIACC Project No. AF 23)
18. Payet R. A. 2006. Sustainability in the context of coastal and marine tourism in Seychelles. PhD Thesis, Univeristy of Kalmar, Sweden. (AIACC Project No. SIS 90).
19. Peras, R. J. J. 2005. Vulnerability and adaptation strategies of Pantabangan-Carranglan watershed communities to climate variability and extremes. MSc Thesis, College of Forestry and Natural Resources, University of the Philippines Los Baños, Philippines. (AIACC Project No. AS21)
20. Pereira, R. A. 2004. Monitoring urban heat island phenomenon in metro Manila: a remote sensing-GIS approach. University of the Philippines Dilman, Philippines. (AIACC Project No. AS21)
21. Perera, H. 2004. Impact of elevated carbon dioxide on coconut seedlings. Undergraduate thesis, University of Peradeniya, Sri Lanka. (AIACC Project No. AS12)
22. Pulhin, F. B. 2003. Assessing the role of wood products in mitigating climate change in the Philippines. PhD Thesis, College of Forestry and Natural Resources, University of the Philippines Los Baños, Philippines. (AIACC Project No. AS21)
23. Sigalla, R. J. 2003. Community response on the impact of climate change on water resources: a case study of Muleba and Biharamulo Districts in Kagera region. MA Dissertation, University of Dar es Salaam, 133p. (AIACC Project No. AF91)
24. Steynor, A. 2005. The impact of global climate change on the runoff and ecological sustainability of the Breede River. MSc Dissertation, University of Cape Town, South Africa. (AIACC Project No. AF07)
25. Utrera, G. 2004. Bioclimatic effects of climate change. Undergraduate Theses, Universidad Veracruzana, 86 pp (in Spanish). (AIACC Project No. LA29)

Final Reports From AIACC Regional Assessments

Final reports from the AIACC project are available at:
http://www.aiaccproject.org/FinalReports/final_reports.html

1. Final Report Project No. AF04 (2006): Impacts and Adaptations to Climate Change in the Biodiversity Sector in Southern Africa.
2. Final Report Project No. AF 07 (2006): The Development of Regional Climate Change Scenarios for Sub Saharan Africa.
3. Final Report Project No. AF 14 (2006): Environmental Strategies to Increase Human Resilience to Climate Change: Lessons for Eastern and Northern Africa.
4. Final Report Project No. AF 20 (2007): Assessing Global and Regional Climate Change Scenarios for West Africa.
5. Final Report Project No. AF 23 (2006): Food Security, Climate Variability and Climate Change in Sub Saharan West Africa.
6. Final Report Project No. AF 38 (2007): Integrated Assessment of Miombo Region: Exploration of Impacts and Adaptation Options in Relation to Climate Change and Extremes.
7. Final Report Project No. AF 42 (2007): Impacts of Climate Change, Vulnerability and Adaptation Capacity in the Limpopo Basin of Semi-Arid Land in Southern Africa: The Case of Eastern Botswana
8. Final Report Project No. AF 47 (2006): Estimating and Comparing Costs and Benefits of Adaptation Projects: Case Studies in South Africa and The Gambia.
9. Final Report Project No. AF 90 (2006): Assessment of Impacts, Adaptation, and Vulnerability to Climate Change in North Africa: Food Production and Water Resources.
10. Final Report Project No. AF 91 (2006): Climate Change Induced Vulnerability to Malaria and Cholera in the Lake Victoria Region (Wandiga, Shem O.)
11. Final Report Project No. AF 92 (2007): Rural Households and Drought in the Sahel Region of West Africa: Vulnerability and Effective Mitigation Measures.
12. Final Report Project No. AS 06 (2006): Climate Change Vulnerability and Adaptation in Livestock Sector of Mongolia.

13. Final Report Project No. AS 07 (2006): Vulnerability to Climate Change Related Water Resource Changes and Extreme Hydrological Events in Southeast Asia
14. Final Report Project No. AS 12 (2007): Assessment of the Impacts of and Adaptations to Climate Change in the Coconut and Tea Sectors of Sri Lanka.
15. Final Report Project No. AS 21 (2006): An Integrated Assessment of Climate Change Impacts, Adaptations and Vulnerability in Watershed Areas and Communities in Southeast Asia.
16. Final Report Project No. AS 25 (2006): Vulnerability and Adaptation to Climate Variability and Change in Western China.
17. Final Report Project No. LA 06 (2007): Impacts and Adaptation to Climate Change and Extreme Events in Central America.
18. Final Report Project No. LA 26 (2005): Global Climate Change and the Costal Areas of the Rio de la Plata.
19. Final Report Project No. LA 27 (2006): Climate Change and Variability in the Mixed Crop/Livestock Production Systems of the Argentinean, Brazilian and Uruguayan Pampas.
20. Final Report Project No. LA 29 (2006): Vulnerability and Adaptation to Climate Change: The Case of Farmers in Mexico and Argentina.
21. Final Report Project No. LA 32 (2006): Vulnerability and Adaptation of Estuarine Systems of the Rio de la Plata.
22. Final Report Project No. SIS06 (2006): The Threat of Dengue Fever in the Caribbean: Impacts and Adaptation.
23. Final Report Project No. SIS 09 (2007): Modeling Climate Change Impacts on Viti Levu (Fiji) and Aitutaki (Cook Islands).
24. Final Report Project No. SIS 90 (2007): Impacts of Climate Change on Tourism in Seychelles and Comoros

Workshop Reports

It's Raining, Its Pouring,...It's Time to be Adapting: Report of the Second AIACC Regional Workshop for Latin America and the Caribbean, Buenos Aires, Argentina, 24-27 August 2004.

Messages From Dakar: Report of the Second AIACC Regional Workshop for Africa and the Indian Ocean Islands, Dakar, Senegal, 24-27 March 2004.

1st AIACC Asia Pacific Region Open Meeting and Workshop, Bangkok, Thailand, 24-27 March 2003.

1st AIACC Africa Region (Including Indian Ocean Islands) Open Meeting and Workshop, Hartebeespoortdam, South Africa, 12-13 March 2003.

AIACC project development workshop: Climate Change Vulnerability and Adaptation, Hosted by the Third World Academy of Sciences, Trieste, Italy, 3-14 June 2002.

AIACC project development workshop: Development and Application of Scenarios in Impacts, Adaptation and Vulnerability Assessments, Hosted by the Tyndall Centre for Climate Change Research, University of East Anglia, Norwich, UK, 15-26 April 2002.

Other Outputs And Related Activities

For Whom the Bell Tolls, Vulnerabilities in a Changing Climate: A Summary of Lessons from the AIACC Project. (2005). Brochure distributed at the COP-11, Montreal, Canada. International START Secretariat, Washington, USA.

A Stitich in Time, Adapting to a Changing Climate: A Summary of Lessons from the AIACC Project. (2005). Brochure distributed at the COP-11, Montreal, Canada. International START Secretariat, Washington, USA.

AIACC: Climate change and conservation planning – This online training course, aimed at the management of biodiversity, is an output of the AF04 project designed for students in the Biodiversity and Conservation Biology (BCB) honors program at the University of the western Cape, South Africa. The scope of the course includes familiarization with current climate change scenarios and equipping learners with the analytical skills necessary for identifying impacts of climate change on biodiversity; identifying adaptation options for mitigation of impacts; and informing conservation planning. Course materials are available at: http://planet.uwc.ac.za/nisl/AIACC/

Climate Change: Health and Economic Development in Sub-Saharan Africa (EMS SC 100S: Section 009): Undergraduate course conducted at Penn State University by Prof. Rob Crane at the Department of Geography. Course curriculum to include selected AIACC case studies in the area of climate change adaptation strategies for food security, infectious diseases, ecosystems and water.

Compact Disc: 1st Latin America and Caribbean Regional Workshop, San Jose, Costa Rica, 27-30 May 2003.

Compact Disc: Climate Change Vulnerability and Adaptation Assessment Methods Training Course. Course materials compiled by the Stockholm Environment Institute (SEI), Oxford, from the AIACC sponsored training workshop hosted by the Third World Academy of Sciences (TWAS) in Trieste, Italy, June 2002.

Compact Disc: AIACC Scenario Workshop, Tyndall Centre for Climate Change Research, University of East Anglia, Norwich, UK, 15-26 April 2002, May 2002 version

Compact Disc: AIACC Africa station and guided perturbation data sets. Produced by the Climate Systems Analysis Group (CSAG), University of Cape Town, South Africa, as a part of the AIACC project, August 2003.

Compact Disc: AIACC Africa Climate Change Scenarios. Produced by the Climate Systems Analysis Group (CSAG), University of Cape Town, South Africa, as a part of the AIACC project, December 2002.

Annex B: Participating Institutions of the AIACC Project

The regional assessments of AIACC encompassed 46 developing countries. More than 350 scientists, experts, stakeholders and students from over 150 institutions in 50 developing and 12 developed countries participated in the project. The partial listing of participating institutions is given below.

Argentina

Instituto Nacional de Tecnologia Agropecuaria
Universidad de Buenos Aires, UBATEC
Universidad Nacional de Río Cuarto
Universidad Nacional de La Plata

Australia

APSRU
Australian National University
Commonwealth Scientific and Industrial Research Organisation (CSIRO) - Australia
GCTE-Australia

Barbados

Caribbean Institute of Meteorology and Hydrology

Belize

Hydrological Department, Met Service

Botswana

University of Botswana

Brazil

Escola Nacional de Saude Publica
Empresa Brasileira de Pesqur isa Agropecuaria (EMBRAPA)
Centro de Prevsao de Tempo e Estudos Climaticos (CPTEC/INPE)

Cambodia

Ministry of Environment

Cameroon

Applied Physics Research Center

Canada

University of British Columbia
University of Toronto

Chile

Universidad de Chile

China

Gansu Grassland Ecological Research Institute
International Institute for Earth System Science (ESSI), Nanjing University
Cold and Arid Regions Environmental & Engineering Research Institute (CAREERI), Chinese Academy of Sciences

Comoros

Ministere de La Production et de L'Environnement

Cook Islands

Environment Service

Costa Rica

Central American Integration System, Comite Regional de Recursos Hidraulicos (CRRH)

University of Costa Rica

Cuba

Instituto de Meteorologia

Denmark

UNEP Collaborating Centre on Energy and Environment

Egypt

Central Laboratory for Agricultural Climate (CLAC), Agricultural Research Center

El Salvador

Met Service

Fiji

University of the South Pacific

The Gambia

Department of Water Resources

Germany

Potsdam Institute for Climate Impact Research
University of Bonn

Ghana

National Center for Mathematical Sciences

Guatemala

Climate Department – INSIVUMEH

Honduras

Climate Change Program-Honduras

Italy

International Center for Theoretical Physics

India

Indian Institute of Technology – Bombay

Indonesia

Bogor Agricultural University
International Center for Research in Agroforestry
Institute Pertanian Bogor

Jamaica

University of the West Indies, Mona

Japan

National Institute for Environmental Studies

Kenya

Drought Monitoring Center - Nairobi
Kenya Medical Research Institute
Kenya National Academy of Sciences
University of Nairobi

Laos PDR

Department of Meteorology & Hydrology
National University of Laos

Malawi

Christian Service Committee
Malawi Met Service
SADC Forestry

Mali

Institute of Rural Economy (IER)

Mongolia

Center for Policy Research
Institute of Animal Husbandry
Institute of Geography
Institute of Meteorology and Hydrology
International Institute for the Study of Nomadic Civilization
Mongolian Academy of Sciences

Mexico

Universidad Nacional Autonoma de Mexico (UNAM)
Universidad de Tamaulipas

Morocco

Direction de la Météorologie Nationale

Mozambique

Nacional Centro Nacional De Cartografica e Teledeteccao (CENACARTA)
Ministry of Environment
Mozambique Met Service
University of Mondlane

New Zealand

International Global Change Institute (IGCI), University of Wakaito

Nicaragua

Climate Change Program - Nicaragua

Niger

EAMAC School of Meteorology

Nigeria

Obafemi Awolowo University
University of Jos
University of Lagos

Panama

Canal Zone Commission

Philippines

Department of Environment and Natural Resources
University of the Philippines at Los Banos
National Irrigation Administration
National Power Corporation

Samoa

South Pacific Regional Environment Programme

Senegal

Environnement et Développement du Tiers-Monde (ENDA)
L'Institut de Recherche pour le Developpement (IRD)
Laboratoire de Physique de l'Atmosphere
Simeon Fongang, Universitie Cheikh Anta Diop
Service Meteorologique

Seychelles

Seychelles Climate Centre, Ministry of Environment
National Meteorological Service

Singapore

National University of Singapore

South Africa

Climate System Analysis Group, University of Cape Town
Council for Scientific and Industrial Research (CSIR) – South Africa
Energy and Development Research Center, University of Cape Town
National Botanical Institute
South African National Parks Board
University of Pretoria
University of Witwatersrand

Spain

University Politecnica de Madrid

Sri Lanka

Coconut Research Institute
Meteorology Department
Sri Lankan Association for the Advancement of Science (SLAAS)
Tea Research Institute

Sudan

Higher Council for Environment & Natural Resources
UNDP/GEF Climate Change Enabling Project

Sweden

University of Kalmar

Tanzania

University of Dar-es-Salam

Thailand

Southeast Asia START Regional Center
Chulalongkorn University
Chiengmai University
Maheidol University
Sukhothai Thammathirat University

Trinidad and Tobago

Caribbean Epidemiology Center (CAREC)

Tunisia

Ministère de l'Agriculture de Tunisie

Uganda

Makere University

United Kingdom

Hadley Center for Climate Prediction and Research, Met Office
International Institute for Environment and Development (IIED)
King's College
Stockholm Environment Institute – Oxford
Tyndall Centre
University of East Anglia
University of Ulster

United States of America

Center for Disease Control
Clark University
Climate Diagnostics Center, NOAA
Columbia University
International Research Institute for Climate Prediction (IRI)
Goddard Institute for Space Studies, NASA
Howard University
Iowa State University
Johns Hopkins University
Lawrence Livermore National Laboratory
Michigan State University
National Center for Atmospheric Research
Natural Resources Ecology Laboratory, University of Colorado
Pennsylvania State University
Stockholm Environment Institute – Boston
University of Arizona
University of California – Berkeley
University of Colorado
University of Oklahoma

University of Michigan
University of Washington
Wesleyan University

Uruguay

IFDC
Instituto Nacional de Investigacion Agropecuaria
Universidad de la Republic
Uruguayan Navy Oceanograhic Bureau

Vietnam

Center for Education and Development

Zambia

University of Zambia
Zambia Met Services

Zimbabwe

Drought Monitoring Center – Harare
Minerals and Energy Policy Center
University of Zimbabwe

International

Global Change SysTem for Analysis Research
and Training (START)
Third World Academy of Science (TWAS)
UN Environment Programme (UNEP)

Twenty-four assessments of climate change vulnerability and adaptation were executed in Africa, Asia, Latin America and Small Island Developing States under the AIACC project. Developing country teams of scientists, technical experts, stakeholders and students from more than 150 institutions and 50 countries conducted the assessments. Outcomes of the project include:

- Advanced knowledge about climate change, climate risks, and adaptation options in developing countries (the Fourth Assessment Report of the Intergovernmental Panel on Climate Change cites AIACC publications more than 100 times);
- Communicated knowledge to stakeholders for adaptation planning and use in National Communications to the UNFCCC;
- Published more than 200 papers, reports and books, of which more than 100 passed scientific peer-review;
- Enhanced capabilities of the 24 assessment teams;
- Established working relationships among numerous scientific and stakeholder organizations for continued collaborations to respond to climate change;
- Facilitated greater participation in and leadership of international science activities; and
- Catalyzed new activities to advance adaptation and capacity building.

Praise for the AIACC project:

> "The record and outputs of the AIACC are impressive" and "benefited substantially the IPCC's Fourth Assessment Report. In view of this success, it is imperative that we build on the experience and achievements of AIACC and develop the next phase of such work to help advance new knowledge for a possible Fifth Assessment Report." (R.K. Pachauri, Chairman, IPCC.)

> "Sound and solid case studies of vulnerability and adaptation have been woefully lacking" . . . the studies from AIACC "begin to bridge the gap . . . they can assist in not only helping countries and communities to climate proof economies but also put the spotlight on the much needed investments that are urgently required to reduce vulnerability." (Achim Steiner, Executive Director, UNEP.)

> "The new knowledge acquired in this project is extensive" and publications from AIACC "are important reading for students and practitioners alike." (Martin Parry, Co-Chair, Working Group II of IPCC.)

> "An excellent addition to the body of knowledge on adaptation to climate change from the developing world." (Saleem Huq, Director, Climate Change Programme, IIED.)

GLOBAL ENVIRONMENT FACILITY

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