

# **Climate Change Vulnerability and Adaptation in Developing Country Regions**

Draft Final Report of the AIACC Project

April 2007

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# **Climate Change Vulnerability and Adaptation in Developing Country Regions**

## **Draft Final Report of the AIACC Project**

A Global Environment Facility  
Enabling Activity in the Climate Change Focal Area  
Project No. GFL-2328-2724-4330

April 2007

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Copies of this report are available from: [www.aiaccproject.org](http://www.aiaccproject.org) and  
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# 1 Introduction

## 1.1 Project Needs, Objectives and Support

Vulnerability to climate change is considered to be high in developing countries due to social, economic and environmental conditions that amplify susceptibility to negative impacts and contribute to low capacity to cope with and adapt to climate hazards. In addition, projected impacts of climate change generally are more adverse for low latitudes, where most developing countries are located, than for higher latitudes. Because of the high level of vulnerability, there is an urgent need in the developing world to understand the threats from climate change, formulate policies that will lessen the risks and to take action. However, in the final stages of preparation of the Third Assessment Report of the Intergovernmental Panel on Climate Change (IPCC), the authors of the report observed that information about the impacts of climate change on important sectors and systems in developing countries such as agriculture, forestry, fisheries, water resources, human health, human settlements and ecological systems is inadequate for understanding key vulnerabilities and planning appropriate adaptive strategies. They also observed that many developing countries have inadequate capacity to systematically evaluate potential impacts and adaptation responses.

Discussion of these observations at the final meeting of authors of the IPCC report in Lisbon Portugal in 2000 led to development of a proposal to the Global Environment Facility (GEF) for a project to enhance the scientific and technical capacities in developing countries to assess the impacts of climate change and design effective adaptation responses, which are needed to formulate national policies and prepare national communications to the United Nations Framework Convention on Climate Change (UNFCCC). Approval of the proposal resulted in implementation of the project Assessments of Impacts of and Adaptation to Climate Change in Multiple Regions and Sectors (AIACC).

The broad level 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. To achieve this objective, the project was designed and implemented to attain three outcomes:

- 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;
- Advancement of scientific understanding of climate change impacts, vulnerability and adaptation; and
- Improvement of links between science and policy communities to enable adaptation planning and action.

The AIACC project is an enabling activity of the Global Environment Facility in the climate change focal area. Primary funding for the AIACC project was provided by a GEF grant of US\$7,500,000. Financial support was also received from the Canadian International Development Agency (US\$100,000), the Rockefeller Foundation (US\$25,000), the United States Agency for International Development (US\$300,000) and the United States Environmental Protection Agency (US\$50,000). The participating developing country institutions provided in-kind co-funding valued at US\$1,800,000.

This report is but one of many outputs of the AIACC project. It provides a synthesis of research findings about climate change vulnerability and adaptation, summaries of results from regional climate change assessments that were executed under the project, a description of the capacity building activities that were implemented to support the climate change assessments, a summary of the project outputs and their uses, an evaluation of project performance, and conclusions and recommendations.

## 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, experts and stakeholders 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).

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.

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, and numerous other publications, including 25 student theses. Many of the AIACC publications are cited in the new IPCC 4<sup>th</sup> Assessment Report and results are being incorporated into national communications to the UNFCCC, providing input to new research and assessment activities, and informing adaptation planning efforts. Two synthesis workshops were held in 2005 to draw common lessons and findings from the AIACC assessments. The synthesis activities produced two book volumes, *Vulnerability to Climate Change* and *Adaptation to Climate Change*, which are collections of peer-reviewed papers that are scheduled to be published by Earthscan in late 2007. The summary chapters from the two books are included as Chapters 2 and 3 of this report. They provide an overview of the main scientific findings from the assessment activities. Summaries of each of the individual climate change assessments are provided in chapters 4 through 7 and their full reports are available on-line at [www.aiaccproject.org](http://www.aiaccproject.org).

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<sup>th</sup> Assessment Report of the IPCC, participants in expert meetings of the UNFCCC SBSTA, and presenters in other international meetings.

Evidence of the effectiveness of the capacity building and networking activities is given by the high scientific output of the assessments, the participation of 30 of the AIACC investigators as authors of the IPCC 4<sup>th</sup> Assessment Report, AIACC participants taking leadership roles in the climate change science and adaptation community, AIACC teams taking responsibility for technical support and capacity building in new climate change initiatives, the continuation of AIACC teams in climate change assessment and their success in winning new grants for new projects. A fuller description of capacity building and networking activities is provided in Chapter 8.

The major outputs of the climate change assessments, capacity building and networking activities and their uses are described in Chapter 9 of the report. Performance with respect to the project objectives and intended outcomes is evaluated in Chapter 10 and conclusions and recommendations are presented in Chapter 11. A complete listing of peer-reviewed and other publications and outputs from the AIACC project appears in Annex A of the report.

### **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 Gobel (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.

*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*

<b>Project No.</b>	<b>Project Title</b>	<b>Administering Institution and Principal Investigator</b>	<b>Countries</b>	<b>Award Amt. (US\$)</b>	<b>Co-funding (US\$)</b>
AS06	Climate Change Vulnerability and Adaptation in the Livestock Sector of Mongolia	Institute of Hydrology and Meteorology, Mongolia. Dr. Punsalma Batimaa.	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*

<b>Project No.</b>	<b>Project Title</b>	<b>Administering Institution and Principal Investigator</b>	<b>Countries</b>	<b>Award Amt. (US\$)</b>	<b>Co-funding (US\$)</b>
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*

<b>Project No.</b>	<b>Project Title</b>	<b>Administering Institution and Principal Investigator</b>	<b>Countries</b>	<b>Award Amt. (US\$)</b>	<b>Co-funding (US\$)</b>
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

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*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. From these varied studies, a number of lessons have emerged regarding climate change vulnerabilities and adaptations. Lessons about adaptation are presented in Burton et al. (2005), while in this paper we present a synthesis of lessons concerning vulnerability. The lessons are generalized from the case studies and provide a broad view of commonalities across places and systems. While useful, vulnerability

to climate change is highly context specific and many rich details are lost in this aggregation. For these details, the reader must go to the individual AIACC case study papers that are referenced in this synthesis.

The synthesis was developed following a protocol described in Section 2 and is structured around four domains of vulnerability to climate change impacts: (i) natural resources, (ii) coastal areas and small islands, (iii) rural economy and food systems, and (iv) human health. The main lessons about vulnerability to emerge from the synthesis and developed in this paper can be briefly stated as follows:

- 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 and therefore incapable of effective response.
- A household's access to water, land and other resources are important determinants of its vulnerability.
- Heightened water scarcity that impedes development is a critical concern for areas that may become drier.
- Land degradation and desertification may also be exacerbated in these areas, posing additional threats to human well-being and development if human pressures on lands intensify and are poorly managed.
- Some ecosystems and many of their species may be lost to climate change, with consequent losses of goods and services to human societies.
- Multiple factors converge to make the people inhabiting coastal zones and small islands highly vulnerable.
- The livelihoods and food security of the rural poor are threatened by climate change. The threat is particularly great for, but not limited to, rural poor in drought-prone dryland areas.
- Vulnerability to adverse health impacts is greater where health care systems are weak and programs for disease surveillance and prevention are lacking.

## **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.

The results, presented in Sections 3 through 6 and summarized in Section 7 of the paper, are a synthesis of our findings about vulnerability. Within the domains of natural resources, coastal areas and small islands, rural economy and food security, and human health we have identified outcomes from exposures to climate change that pose risks of national level concern. For each of these outcomes, the main climatic and non-climatic drivers are identified.

## **2.3 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; 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.

### **2.3.1 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 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 glacier	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	North Darfur, Sudan (Sanjak et al., 2005) Northern Nigeria (Nyong et al., 2005) Mongolia (Batima et al., 2005) Mexico (Eakin et al., 2005)
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., 2005) Philippines (Pulhin et al., 2005) South Africa (Nkomo et al., 2005)
	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., 2005) Argentina (Barros et al., 2005) Thailand & Lao PDR (Chinvanno et al., 2005) Philippines (Pulhin et al., 2005)
Low	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., 2005) Western China (Yin et al., 2005) Thailand & Lao PDR (Chinvanno et al., 2005) South Africa (Nkomo et al., 2005)

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. Sanjak et al. (2005) and Nyong et al. (2005) 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 5.3).

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., 2005), 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., 2005). 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., 2005, Eakin et al., 2005, and Camilloni and Barros, 2003), the Philippines (Pulhin et al., 2005), and Lower Mekong River basin (Suppakorn et al., 2005), 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. 2005), 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., 2005). 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., 2005). 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.

### 2.3.2 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

*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	North Darfur, Sudan (Sanjak et al., 2005) Northern Nigeria (Nyong et al., 2005)
	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	North Darfur, Sudan (Sanjak et al., 2005) Northern Nigeria (Nyong et al., 2005) Mongolia (Batima et al., 2005) Mexico (Eakin et al., 2005)
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	Mexico (Eakin et al., 2005) Philippines (Pulhin et al., 2005)

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., 2005) Philippines (Pulhin et al., 2005)
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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 (Sanjak et al., 2005) and the other in Mongolia (Batima et al., 2005), 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., 2005), Tlaxcala, Mexico (Ziervogel et al., 2005), and Tamaulipas, Mexico and the Argentine Pampas (Eakin, et al., 2005).

Table 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.

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 (Sanjak et al., 2005). 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., 2005). The human consequences of drought and land degradation in Sudan are explored below in Section 5.3. 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. (2005). Over the past 40 years, pasture production has declined 20-30%. 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 5.2 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.

### 2.3.3 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, 2005) and the Philippines (Lasco, et al., 2005) 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 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.

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.

*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 <sub>2</sub> in atmosphere	South Africa (von Maltitz & Scholes, 2005) Philippines (Pulhin et al., 2005)

Medium	Species loss and retrogressive succession	Greater water stress from higher temperatures and lower precipitation	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 <sub>2</sub> in atmosphere	South Africa (von Maltitz & Scholes, 2005)
	Species loss and change in habitat compositional structure	Slow changes in climate that allow most species to migrate	Sufficient connections of suitable habitat persist across the landscape to enable species to migrate	South Africa (von Maltitz & Scholes, 2005)
Low	Genetic loss Loss of genetic variability, loss of sub-species and varieties	Slow changes in climate Small absolute changes in temperature and precipitation that do not fundamentally alter water balances	More severe effects kept in check by: Managing pressures on ecosystems to a low level Connections of suitable habitat enable species to migrate	South Africa (von Maltitz & Scholes, 2005)

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., 2005). 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.

## 2.4 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.(2005) investigate flood risks from storm surges along the Argentine coast of the Rio de la Plata. Nagy et al. (2005), 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 and De Comarmond (2005) explore problems of coastal erosion and also risks to tourism in the Seychelles, while Mataka et al. (2005) assess the vulnerability of coastal towns of Fiji to flooding. Outcomes of concern from these studies are summarized in Table 4.

Barros et al, (2005) 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

*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, ( <a href="http://www.aiaccproject.org">www.aiaccproject.org</a> ; LA06) Argentina (Barros et al., 2005)
	Loss of tourism related income, export earnings and jobs	Changes number of wet days, 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 and De Comarmond, 2005)
	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 and De Comarmond, 2005) Fiji (Mataka et al., 2005)
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., 2005)

	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)
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., 2005)

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. (2005) 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 and De Comarmond, 2005) and in Fiji and the Cook Islands (Mataki et al., 2004), 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 and De Comarmond, 2005). 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 and De Comarmond estimate 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., 2005). 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.

## 2.5 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 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).

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

*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, other resources	North Darfur, Sudan (Sanjak et al., 2005) Northern Nigeria (Nyong et al., 2005)

	Multi-year collapse of rural production systems Widespread and persistent loss of livelihoods & impoverishment Chronic hunger & malnutrition for large % 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 % of households engaged in subsistence or small-scale farming and herding on lands with poor soils and no irrigation Over-use, 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	North Darfur, Sudan (Sanjak et al., 2005) Northern Nigeria (Nyong et al., 2005) Mongolia (Batima et al., 2005)
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 crop(s) 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 & diffusion of agricultural technology	Sri Lanka (Ratnisiiri et al., 2005)
	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 & 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 & Mexico (Eakin et al., 2005) South Africa, Nigeria, Sudan & Mexico (Ziervogel et al., 2005) Thailand & Lao PDR (Chinvanno et al., 2005) Philippines (Pulhin et al., 2005)
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 & 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 & Mexico (Eakin et al., 2005) Thailand & Lao PDR (Chinvanno et al., 2005) Philippines (Pulhin et al., 2005) Sri Lanka (Ratnisiiri et al., 2005)

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.

### 2.5.1 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. (2005) 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 (2005) 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. (2005) 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., 2005). 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. (2005) 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. (2005) 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.

## 2.5.2 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., 2005), Sudan (Sanjak et al., 2005), Nigeria (Nyong et al., 2005), the Philippines (Pulhin et al., 2005), Argentina and Mexico (Eakin et al., 2005).

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 3.2, these conditions have depressed pasture productivity and livestock production. Batima et al. (2005) 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., 2005).

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., 2005). 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., 2005). 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., 2005). 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.

## 2.5.3 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., 2005). 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., 2005). 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. (2005) find that food scarcity and rising food prices have led 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.

#### **2.5.4 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. (2005) 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.

#### **2.5.5 Market forces and social safety nets**

The case studies by Eakin et al. (2005) 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.

## 2.6 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 6 and are described below. Indirect health effects are briefly summarized in Section 6.2.

*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 health care system Poor and declining immunity, nutritional and health status of large portion of population High poverty rates that limit access to health care Poor or non-existent programs 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., 2005) Caribbean (Heslop-Thomas et al., 2005)
	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 programs for disease surveillance, vector control, and	East Africa (Wandiga et al., 2005) Caribbean (Heslop-Thomas et al., 2005)

			disease prevention Declining quality and increasing cost of health care	
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 health care 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., 2005) Caribbean (Heslop-Thomas et al., 2005)

## 2.6.1 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., 2005; Heslop-Thomas et al., 2005; 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., 2005). Other studies suggest that, if El Niño events continue to increase in frequency, the elevated temperatures and precipitation would increase malaria transmission (Kilian et al. 1999; Lindblade et al. 1999). In rural communities of the highlands studied by Wandiga et al. (2005), 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., 2005).

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 8). Where the converse of these conditions hold, the likelihood that the most severe health outcomes would be realized is much diminished.

## **2.6.2 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.

## **2.7 Conclusion**

Vulnerability to impacts from climate variation and change is shown by the regional studies of the AIACC project to have multiple causes and dimensions. The causes include not only the climatic stressors, but also 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 phenomenon are not 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 household members' livelihoods, level of wealth, ownership and access to resources, and knowledge of risks and possible responses give rise to differences in vulnerability across households.

We focus on four domains of vulnerability (natural resources; coasts and small islands; rural economy and food security; and human health) and identify and rank climate related outcomes of concern. For each of the outcomes of concern, climatic and non-climatic determinants are identified. A common finding across the domains of vulnerability is that devastating 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 so 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. Examples include famine, collapse of rural livelihood systems that deepen and widen poverty, and loss of life from widespread and persistent epidemics of infectious disease.

An exception is the potential loss of some ecosystems and 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 most ecosystems, it will be the interaction of a changing climate with pressures from human uses and management of land and other resources that likely will 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 health care system that is effective at delivering services to a population, combined with public health programs that promote preventive behaviors, 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 access to all manner of resources that can help them to cope with and overcome climate related impacts. Findings from AIACC about the capacity to adapt and adaptation strategies are explored more fully in Burton et al., 2005.

These and other examples indicate that improving the performance of human systems can reduce vulnerability. 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.

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

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#### 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. 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 a companion to this volume (see Leary et al, 2007). Here, in this volume, we collect together papers from the AIACC studies that explore the challenge of adaptation.

Comparison and synthesis of our individual contributions 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 resides that must be engaged.

### **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, 2007). 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 (Batimaa et al, 2007; Osman et al, 2007; and Dube et al, 2007). 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, 2007, and Yanda et al, 2007). 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. Exposure to climate hazards has 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, 2007). An important

consequence of climate change for adaptation is that the future climate will be less familiar and in key respects more uncertain.

Another important difference is that 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°C by end of the 21<sup>st</sup> century relative to 1980-1999 temperatures (IPCC, 2007). 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. Confidence in predictions of precipitation trends is less than for temperature trends. However, 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 experience of Argentina in the last decades of the 20<sup>th</sup> century are instructive of some of the challenges (Barros, 2007). 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, 2007). 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 hoppers). 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 per cent of species would be persisters, 26 per cent partial dispersers, 6 per cent obligatory dispersers, and 11 per cent would be no hoppers.

The no-hoppers 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-hoppers, 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, 2007). 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, 2007). 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, 2007; Dube et al, 2007; Chinvarno et al, 2007; Mougou et al, 2007; Wehbe et al, 2007; Dabi et al, 2007; and Osman et

al, 2007). 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, 2007). 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, 2007).

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, 2007).

The case studies of northern Nigeria (Dabi et al, 2007) and the states of North Kordofan, North Darfur and Red Sea in Sudan (Osman et al, 2007) 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, 2007). 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, 2007). Similarly, in Tamaulipas, Mexico, *ejidatarios* and smallholder farmers lack know-how for adopting irrigation (Wehbe et al, 2007). In Mongolia, herders voiced a strong need for education and training in methods for improving the condition and productivity of their rangelands and livestock (Batimaa et al, 2007). 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, 2007).

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 (2007), 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, 2007). 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 (Batimaa et al, 2007). 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, 2007). 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 20<sup>th</sup> 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 per cent 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 (Munich 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 (2007), 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% 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 per cent of the population that was exposed to natural disasters in 1980-2000 but account for only 1.8 per cent 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 per cent 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, 2007, and Lasco et al, 2007).

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, 2007). 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, 2007).

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 per cent of average annual flows and conflicts have arisen between competing water users (Yin et al, 2007). 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, 2007). 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, 2007), countries of the lower Mekong (Chinvanno et al, 2007), Mongolia (Batimaa et al, 2007), and Sudan (Osman et al, 2007). 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 et al, 2007).

### **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 et al (2007) of community development efforts in Sudanese villages of Bara Province in North Kordofan, 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, 2007). 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, 2007). 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 measures 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 (2007) 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 per cent. Under the current regulatory regime for water allocation and water demand growth of 3 per cent 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 per cent 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 per cent 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 per cent by allowing efficient reallocation of scarce water.

Njie et al (2007) 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 per cent 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 (2007) 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 north-western 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 (2007) 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 (Batimaa et al, 2007). 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 harsh 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, 2007). 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 manage 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.

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## 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](http://www.aiaccproject.org/Final Reports/final_reports.html)

### 4.1 Impacts and Adaptations to Climate Change by the Biodiversity Sector in Southern Africa (AF 04)

#### 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 (South Africa, 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 potential actions for adaptation to these impacts given the inevitability of climate change (IPCC TAR, 2001). The South African climate change research community 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 for the use of officials with a mandate and responsibility for 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 conservation planning tools for the prioritization of conservation planning in an environment, which is non-static, as a result of climate and land use change.
3. Evaluate, in terms of economic costs and effectiveness, adaptation options for biodiversity conservation when faced with climate change and a fragmented landscape. This will involve the development of a cost-effectiveness evaluation method, and testing and illustrating it using diverse southern African examples as to how the climate change induced mitigation of biodiversity can be incorporated in the new move towards strategic conservation planning.
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 21<sup>st</sup> century.

5. Advance the field of dynamic biodiversity conservation and develop capacity in both 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, to more sophisticated ones involving more robust statistical approaches, 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 were grouped into the following functional groups:

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 hoppers*: 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:

- 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.

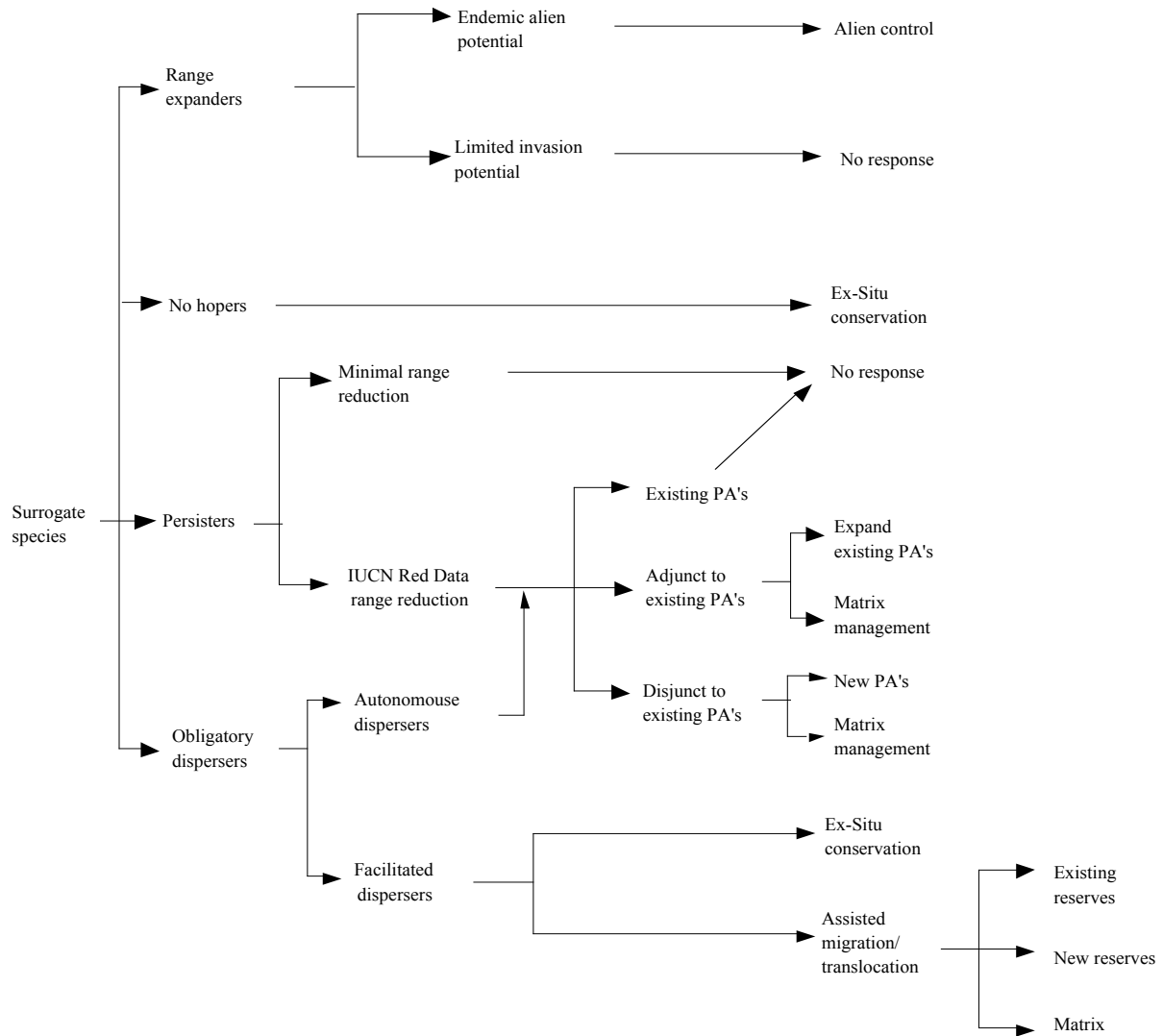


Figure 4.1: A decision tree for selecting adaptation strategies for different surrogate species based on their response to climate change (Adapted from Midgley et al in prep).

## Scientific findings

Rapid advances in individual species dispersion modeling techniques between our conceptualization of the project, and actual implementation, allowed us to develop 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% of species had no future habitat and 6% would need to move to new locations. Results from this study were used to review strategic conservation strategies for the region. In addition the 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.

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 signatus*). 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 north-eastern lowveld savanna. The model considered both the impacts of temperature and rainfall, as well as changes in CO<sub>2</sub> 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 the 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 of biodiversity given climate change. 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 10 SADC countries and a number of South African institutions. Parts of the research findings from the project have been incorporated into the 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 national team's UNFCCC COP9 negotiations. This memo indirectly precipitated the increase 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 WG panels i.e. Dr Bob Scholes: IPCC WG3 group on agriculture and Dr Guy Midgley: IPCC WG2 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, Zimbabwe

**Principal Investigator:** Dr. Bruce Hewitson

**Administering Institution:** University of Cape Town, South Africa.

### ***Research problem and objectives***

Africa encompasses some of the world's regions most vulnerable to climate change. This is compounded by the issues of 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, which increases 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 westernized nation modeling activities 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 attempts to address these concerns with the objectives of:

- Capacity development within 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 so far, 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 remaining uncertainty surrounding the magnitude, pace and character of future climate change, there is an urgent need for Africa to build its capacity 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.<sup>1</sup> 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.
- 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

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<sup>1</sup> While recent climate modelling (see Hoerling, Martin P., James W. Hurrell, and Jon Eischeid. "Detection and attribution of 20th century northern and southern African monsoon change." Submitted to Journal of Climate) suggests that the Sahel may become wetter on average in the future, there is significant uncertainty surrounding this and other modelling efforts; if such research proves to be accurate, drought and dry spells would almost certainly continue to be a major factor in the region.

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.

- Case studies compared a community's resilience to climate extremes, before and after project activities.
- Case studies were conducted by commissioned researchers, by means of desk-based and field research over a six-month period.
- 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?).

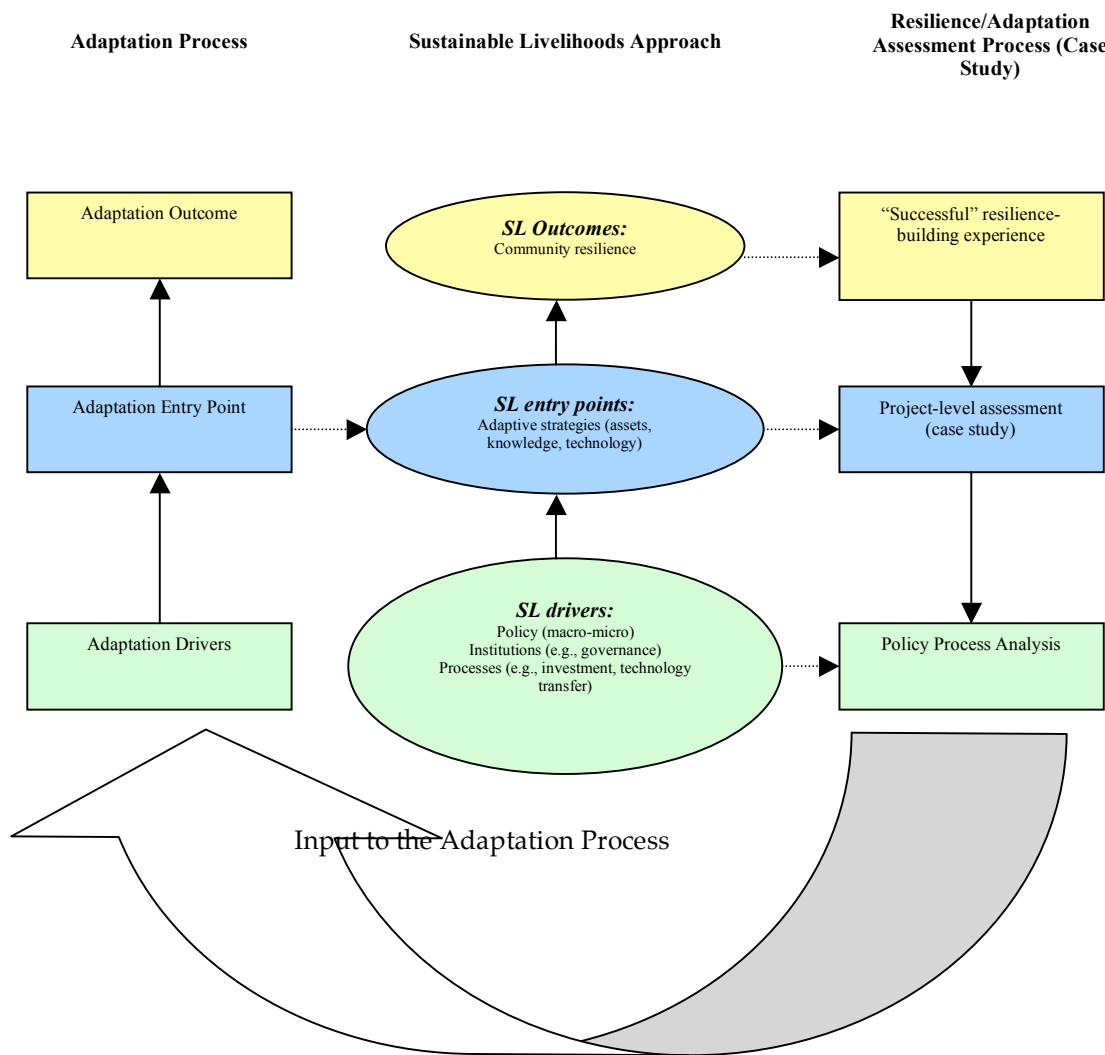


Figure 4.2: Adapted version of the UNDP approach to sustainable livelihoods

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.

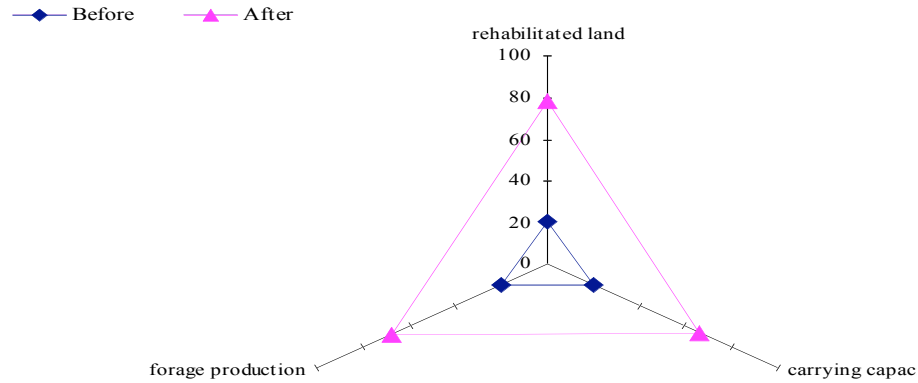
### ***Scientific findings***

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:

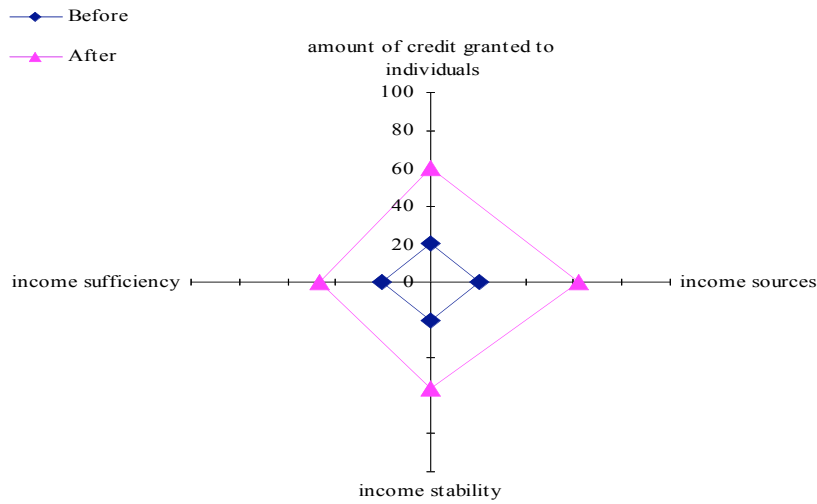
- Strategies and measures for the sustainable management of natural resources can support broad improvements in livelihood security and household and community capacity to cope with climate impacts. Specific examples observed include both autonomous natural resource management (NRM) efforts, such as 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.



*Figure 4.3: Assessment of productivity of natural capital before and after intervention of rangeland rehabilitation project, using rehabilitation of rangeland, carrying capacity and forage production as indicators.*



*Figure 4.4: Assessment of productivity of financial capital before and after intervention of the Rangeland Rehabilitation Project, based on availability of information, effectiveness of credit repayment, suitability of local institutions, and support of credit systems and government policy to income-generating activities.*

### ***Capacity building outcomes and remaining needs***

The methods used in this project represent one approach to 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 for such teams, 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 what has been captured 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 Food Security, Climate Variability and Climate Change in Sub Saharan West Africa (AF 23)

### 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 21<sup>st</sup> 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 21<sup>st</sup> 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.  $V = f(\text{exposure, sensitivity, adaptive capacity})$  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 7.5° N. A sub-humid climate (Koppen's Aw) characterizes the region between latitudes 7.5° and 9.5° N. 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 20<sup>th</sup> 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 21<sup>st</sup> 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 5° C 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 day time 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 20<sup>th</sup> Century will be put on hold or reversed as the 21<sup>st</sup> 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. Cow pea 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 21<sup>st</sup> 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 yield 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 of the present situation 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" of 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 resilience of the 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 foreknowledge 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.

## 4.5 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 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, Extremes: 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 were prepared for climate data 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 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.

*Table 4.1: Main adaptation activities, interventions and delivery methods*

<b>Adaptation Goals / Expected Outcomes</b>	<b>Main line of intervention and delivery</b>
Minimize physical exposure to climatic hazards	<ul style="list-style-type: none"> <li>• 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</li> <li>• Drought mitigation measures such as improved water management/water harvesting</li> <li>• Re-zoning sites vulnerable to landslides</li> <li>• Frost control measures such as watering or covering crops/plants at night</li> <li>• Migration or relocation away from flood zones, coastal areas, etc</li> <li>• Global mitigation of climate change through reductions in GHG emissions</li> <li>• Improved water treatment to avoid contamination from flood waters, salinization</li> </ul>
Avoid or reducing potential for adverse impact (climate proofing)	<ul style="list-style-type: none"> <li>• 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</li> <li>• Economic instruments to reduce sensitivity to climate e.g. insurance</li> <li>• Manipulate systems (such as ecosystems and infrastructure) to withstand new climatic conditions through crop/tree breeding or genetic manipulation</li> </ul>
Enhance adaptive capacity and resilience (address determinants of adaptive capacity)	<ul style="list-style-type: none"> <li>• Increase wealth/income especially of rural poor through economic diversification, access to micro-finance</li> <li>• 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</li> <li>• Reduce risk to climate change and variability through (micro-) insurance</li> <li>• Improve ecosystem integrity through reduced siltation and erosion control, fire control, eradication of invasive species, avoid overgrazing, rehabilitate degraded areas</li> </ul>
Improve planning to take changing climate into account to avoid an adaptation deficit and to remove any barriers to adaptation	<ul style="list-style-type: none"> <li>• Modify planning processes to integrate climate change and adaptation into sectoral and national plans (mainstreaming)</li> <li>• Remove barriers through policy review and/or development of new policies to facilitate adaptation</li> </ul>
Create and manage information to facilitate adaptation	<ul style="list-style-type: none"> <li>• Build knowledge bases through research, monitoring, extension and outreach, early warning systems, etc., to improve adaptation planning and implementation</li> <li>• Build capacity in communities to take climate change into account</li> </ul>

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.

### ***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, Siteo, 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.

## **4.6 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.

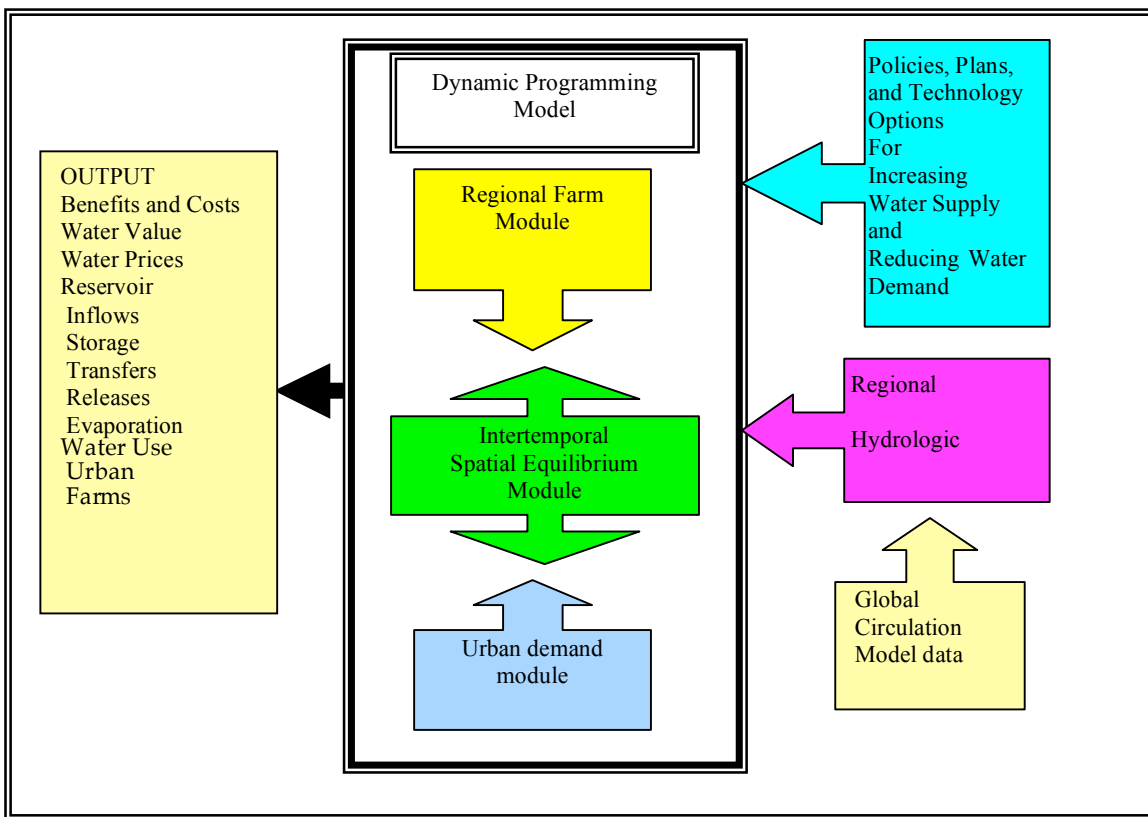
### **Part I. Adaptation to Climate Change: The Berg River Basin Case Study**

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% 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.



*Figure 4.5: Berg River Spatial Equilibrium Model (BRDSEM) Schematic Diagram*

The core of BRDSEM, shown in the figure 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.

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, is 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, the study used the Soil-Water-Atmosphere-Plant (SWAP) model - an integrated physically based 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<sup>-1</sup> respectively with a coefficient of variation (cv) of 30% for both parameters. The HADCM3 ('no regrets') results for average rainfall and yield for the near future were 882 mm and 1141 kg<sup>-1</sup>, with a cv of 33% for both parameters, whilst for the distant future, average rainfall and yield were 510 mm and of 243 kg<sup>-1</sup>, with cvs of 52% and 123% respectively.

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

	<i>HADCM3</i>		<i>ECHAM4</i>	
	<i>average</i> <i>(kg ha<sup>-1</sup>)</i>	<i>CV (%)</i>	<i>average</i> <i>(kg ha<sup>-1</sup>)</i>	<i>CV (%)</i>
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. With the exception of the 'no adaptation' option all the other options showed yield increases ranging from 9 to 37% as compared to the base case (1141 kg<sup>-1</sup>). 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)*

	<i>Average (kg ha<sup>-1</sup>)</i>	<i>Yield</i>	
		<i>Change (%)</i>	<i>CV (%)</i>
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% of total cost of irrigation using diesel-based water-lifting technologies. The corresponding value for solar pumping is 25%, whilst labour accounts for 2 – 5% 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 off 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 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***

Based on the experience gained from this study, the following recommendations for future research are made:

Modify the BRDSEM model to include characterization of the entire Boland Region in the Western Cape by means of: a) Including runoff sources for, and the dynamic water balances in, all of the reservoirs in the area; and 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.

Conduct research to gather data and 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 the principles of equity and economic efficiency in urban water pricing in South Africa.

Add additional storage and non-storage capacity options for increasing water supplies and water use efficiency and reducing water losses in the basin. BRDSEM must be updated by including the possibility for additional storage capacity in the region, based on proposed plans and estimated costs. In addition, the water supply and cost data must be updated for wastewater recycling and desalinization of seawater. Finally, there is a need to include possibilities for reducing water losses and the associated costs of these options in water delivery to users by the Cape Town water authority and for the conveyance systems used to deliver irrigation water to the regional farms.

Improve the representation of water market transfers and include the costs of water market transactions. In the current study, simply removing constraints on agricultural water diversions and urban water demand

simulates efficient water markets. However, this does not take into account how the current ownership of water rights and existing allocation of entitlements can be changed by specific transfers, nor does it include the transactions costs associated with these transfers.

Develop a broader range of policy options 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.

Work closely with regional climate modelers in South Africa to implement BRDSEM using stochastic climate scenario data to generate downscaled distributions of monthly average temperature and precipitation data and transform this into stochastic runoff so that it is more useful to water resources planners.

This study represents an important step in bridging the communication and data gap between climate scientists and water planners. It allows water planners to work with climate change data on essentially the same basis as with observed geophysical records, while account for inherent reliability problems in existing global and regional models to reproduce the 'historical' climate.

For Gambia, 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.

## **4.7 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 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 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.

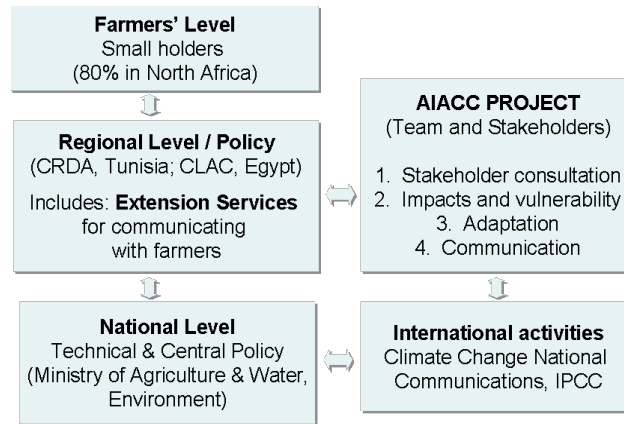


Figure 4.6: Linkages of the AIACC project team with stakeholders in North Africa

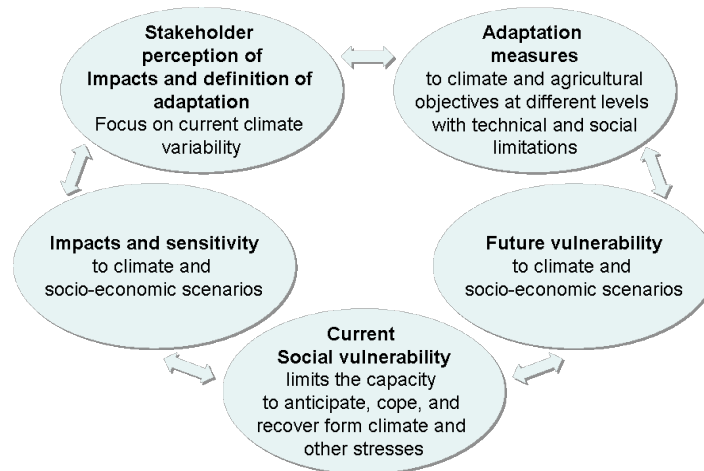


Figure 4.7: Outline of the study protocol

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.

Two 'case studies' - Tunisia and Egypt - are 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 focuses 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 focuses 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 is 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.
- For the study sample, farmers with 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 change in 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 produce results that 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. 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*

<b>Adaptation measure</b>	<b>Potential value for improving production under climate change</b>	<b>Feasibility of adoption for the farmer</b>	<b>Environmental or social limitations to measure</b>
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 that 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 have been defended, and about seven are in the analyses and writing phase. Important experiences for most of project the 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 2<sup>nd</sup> National Communication of Egypt to the UNFCCC. This task is expected to begin in 2006. The principle investigator of this project, Mahmod Medany is participating in the Fourth Assessment Report as a lead author in WG II, chapter 09 - Africa. The results of this have been presented by project investigators in a number of national level lectures, conferences and meetings, as an interaction between the project team and policymakers.

The project has enhanced stakeholder (farmers, extension service staff and agriculture advisors) engagement in defining adaptation measures, thus strengthening the relation between the scientific team and the agricultural society. It has also helped the project team to identify some of the 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 rural society situation.

## **4.8 Climate Change-Induced Vulnerability to Malaria and Cholera in the Lake Victoria Region (AF 91)**

### **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.

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% of the total global cholera cases were reported in Africa. The Lake Victoria region 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 AF\_91 project will be contained in the report of this committee. Three of the project team members are also contributors to the IPCC 4<sup>th</sup> Assessment Report.

Two National consultative meetings which brought together the research teams, government policy-makers (Ministries of Health, Environment and Natural Resources) and UNFCCC 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 ITNs 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 Kenya team of the AF 91 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.

## 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 of 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](http://www.aiaccproject.org/Final%20Reports/final_reports.html)

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

#### Summary Information

**Country:** Mongolia

**Principal Investigator:** Punsalma 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 in rise, which enhance vulnerability of the Mongolian rangelands, livestock and people.

Taking into account the country's specific circumstances of natural resources and agricultural development, the overall objective of this project was to determine the potential impacts of climate change and assessment of vulnerability and adaptation options for rangeland and livestock in Mongolia. Therefore, 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 existing long-term plant dynamics, animal and climate database, ecosystem animal modeling, remote sensing and GIS technology, field and participatory survey 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 below.

### *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 Inter-governmental Panel on Climate Change's (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 referred to 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 0.9°C to 8.7°C, while the summer temperature increase is projected to vary from 1.3°C to 8.6°C; 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; c) In contrast with 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.

Water resources: 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 °C temperature increase, at least a 2 per cent decrease of annual flow is projected.

Snow cover: 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 per cent of the country's territory is covered by snow for more than 50 days in a year, the actual duration depending varying as per geographical location. Snow plays an important role in livestock herding, since it serves 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 duration of more than 140 days is expected to decline while the area of snow cover with 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 per cent 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<sup>0</sup>C to 0.15<sup>0</sup>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 per cent 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 per cent of its annual feed intake from the 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 are high mountains, forest-steppe, steppe and desert and pasture yields are strongly affected by climate and weather conditions.

It has been observed that the peak of pasture biomass has declined by 20 to 30 percent over past 40 years and a clear decline in the Normalized Difference Vegetation Index (NDVI) in 69 per cent of the country's territory for the last 20 years has been noted. Other study observations include: A decline in the fodder production to about one third of that in 1986; a decrease in spring biomass in the forest-steppe and the steppe; pasture plants emergency beginning earlier in the forest-steppe and the steppe; and a 1.5-2.3 times decrease in high nutrient plants over the last 60 years while low nutrient plants have become dominant in pasture communities. 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 north-western mountainous region. Observed data show a decline of 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 and Tuvaansuren, 2002). Sheep wool productivity has decreased by more than 8 per cent, while cashmere productivity has decreased by about 2 per cent over the last 20 years. Animals exhibited temperature stress with climate warming. 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 per cent, while winter ewe live-weight is expected to decrease by 15 per cent 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 associated with global warming. Since more than 80 per cent of the country's territory has been defined as highly vulnerable to climate extremes, the increased incidence of drought and dzud pose as key risks for livestock. The area where climatic conditions would make it hard for animals to graze is projected to increase from the current 40 per cent to about 70 per cent by 2050, and 80 per cent by 2080. 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 per cent by 2050 and 40-60 per cent by 2080.

Drought: Over the last 60 years a 95 percent increase in droughts has been observed with a rapid worsening in the situation in the last decade. The worst droughts Mongolia experienced was in the consecutive summers of 1999, 2000, 2001, and 2002, which affected 50-70 per cent 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.

The animals in Mongolia take the necessary energy and nutrients for growth in summer and autumn build weight to sustain them through the harsh winters. 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 overcome winter and therefore, they die in large numbers. Drought It 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 Mongolia had to request international relief assistance. Such long-lasting (three consecutive years) winter *dzud* followed by summer drought have not occurred in Mongolia in the last 60 years. 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 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 enhance the livelihood of Mongolia's rural community.

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 <i>dzud</i> ) 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 <i>dzud</i> .
	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 animal bio-capacity	Improve shelter for animals	M	H	H	M	M	F	reduced vulnerability to climate extremes not only <i>dzud</i> 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/ <i>dzud</i> ,
	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 community	Promote collective communities	M	H	M	H	M	S&m	increased capacity to cope with climate driving disasters 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	L	H	M	H	H	m	increased financial capacity

	income							
	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.								

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

### ***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.

Information on strategies to reduce of vulnerability to climatic impacts shared with local herders and administrators and their inputs 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 (AS 07)**

### **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 impacts of climate change on the hydrological regime and fresh water resources in Mekong River Basin?
- What are 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 impact of climate change?
- How would rain-fed farmers in the region adapt to impact of climate change?

#### Objectives:

- To develop high resolution climate scenario - in geographical and temporal terms
- To understand the impact 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 impact.
- To understand coping capacity and adaptation to climate impact of the rain-fed farmer in the lower Mekong River region.

#### *Approach*

This study can be divided into 2 parts, which used different approaches in the study.

- The study on climate change and its impact on biophysical systems is based on the 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 region. Climate model was used to simulate high resolution future climate scenario. Climate change impact was analyzed by using future climate data from the simulation as input to the hydrological model and crop model for further simulation on hydrological regime of the Mekong River sub-basins and potential crop productivity yield in the study sites.  
The study of the climate change in Lower Mekong River Basin is based on high-resolution regional climate scenario, which was simulated for the Southeast Asia region by regional climate modeling technique. The Conformal Cubic Atmospheric Model (CCAM), which is the second-generation regional climate model developed specifically for Australasian region and developed by CSIRO Division of Atmospheric Research in Australia, was used. The study of the climate change impact on hydrological regime was based on the Variable Infiltration Capacity (VIC) hydrological model. Decision Support System for Agro Technology Transfers (DSSAT version 4.0) crop modeling software (Hoogenboom et al, 1998) was used to simulate future potential yield of rice productivity in the region under different climate conditions from the scenarios simulated by climate model.
- Assessment of vulnerability and adaptation to climate impact were based on field survey by individual household interviews and focus group meeting. The analysis of field interview data was based on quantitative analysis and multi-criteria method, which used multiple criteria and indicators developed for this case study. The three criteria used in this study in the assessing farmer's risk of climate impact are household economic condition, dependency on on-farm production and coping capacity to climate impact. Adaptation to climate change was also assessed by field interviews and local stakeholders meeting, which mainly focus on the opinion of the 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<sub>2</sub> concentration level. However, the analysis and verification/adjusting process was focused on the Lower Mekong River basin in Lao PDR, Thailand and Vietnam only due to the limited availability of observed climate data.

The climate scenario shows that the region tends to get slightly cooler at CO<sub>2</sub> concentration of 540ppm but will be warmer at CO<sub>2</sub> concentration of 720ppm. The change in temperature under this set of climate scenarios is within the range of 1-2 °C, but the change in the number of annual hot and cool days will be prominent. Hot days, i.e. days with maximum temperature over 33°C, will increase by 2-3 weeks and cool

days, defined as days with minimum temperature under 15°C, 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% increase throughout the region under future atmospheric CO<sub>2</sub> 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*

As the CCAM climate model generated a snap shot of one-decade climate conditions under different CO<sub>2</sub> concentrations, data on wettest year and driest year of the decade were used for hydrological regime simulation, in order to analyze the plausible range of hydrological change under future climate condition. 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 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.

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

<b>Impact of climate change on rice productivity</b>					
Remark: Rice yield shown in kg/ha					
<b>Location</b>	<b>Climate condition under different atmospheric CO<sub>2</sub> concentration</b>			<b>Change in % compare to baseline period</b>	
	<b>360 ppm</b>	<b>540 ppm</b>	<b>720 ppm</b>	<b>540ppm</b>	<b>720ppm</b>
<b>Lao PDR</b> <b>Savannakhet Province</b> Songkhone District	2,534.90	2,303.20	2,470.10	-9.14	-2.56
<b>Thailand</b> <b>Ubonratchathani Province</b> 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
<b>Viet Nam</b> <b>An Giang Province</b> 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
<b>Can Tho Province</b> 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
<b>Dong Thap</b> 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
<b>Long An Province</b> 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

From the mathematic model simulation using DSSAT crop model, the result shows that future climate conditions may have slight negative impact on the rain-fed rice production in the study site in Lao PDR, Savannakhet province with about a 10% reduction in yield at CO<sub>2</sub> concentration of 540 ppm but a reversion to baseline yield at CO<sub>2</sub> 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% 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<sub>2</sub> concentration of 540 ppm, but will drop slightly from baseline year at CO<sub>2</sub> concentration of 720 ppm. On the other hand a significant decline is observed in the summer-autumn crop productivity by approximately 8-12% at CO<sub>2</sub> concentration of 540 ppm and by almost 50% in some areas at CO<sub>2</sub> 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 surveyed data, which focused on change in rice productivity under different climate scenarios and its impact on farmers' livelihood condition, showed that vulnerability is site-specific condition, which depends upon the degree of climate impact and socio-economic condition as well as physical condition 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<sub>2</sub> concentration of 540ppm, over 80% of surveyed population in Lao PDR is classified under the low risk category, while approximately 10% is at moderate risk and only slightly over 5% 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% of the surveyed population comprise the moderate risk group. Climate change has 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<sub>2</sub> concentration of 720 ppm and CO<sub>2</sub> 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 farmer 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 based upon



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 toward 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 their 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. The activities under this research served as a hand-on exercise for the researchers to conduct studies on climate change related issues.

This project has also contributed to the formation of a network of more than 20 researchers and research assistants from 3 countries, who actively participated in 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 impact 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 Asia region. In addition, increasing local research capacity, creating further network of collaboration among institutions and creating a forum for the exchange of research results and 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 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 Chinvanho, 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 and 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 forecast, 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 An Integrated Assessment of Climate Change Impacts, Adaptations, and Vulnerability in Watershed Areas and Communities in Southeast (AS 21)**

### **Summary Information**

**Country:** Philippines and Indonesia

**Principal Investigator:** Dr. Rodel D. Lasco

**Administering Institution:** Environmental Forestry Programme (ENFOR), University of the Philippines Los Baños College, Laguna, Philippines and Bogor Agricultural University, Bogor, 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 Working Group II, 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 Working Group II, 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% 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, majority of who 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% to 32% 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 (SME, 1998). In the last decade, during El-Nino 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<sub>2</sub> on Indonesia's rainfall, forest productivity and crop production has also been evaluated (Boer *et al.*, 2000a; Boer and Team 2000; Amien *et al.*, 1996). Under CO<sub>2</sub> 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 SE 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 Ecija Province. In Indonesia, the study was conducted in Citarum Watershed in West Java.

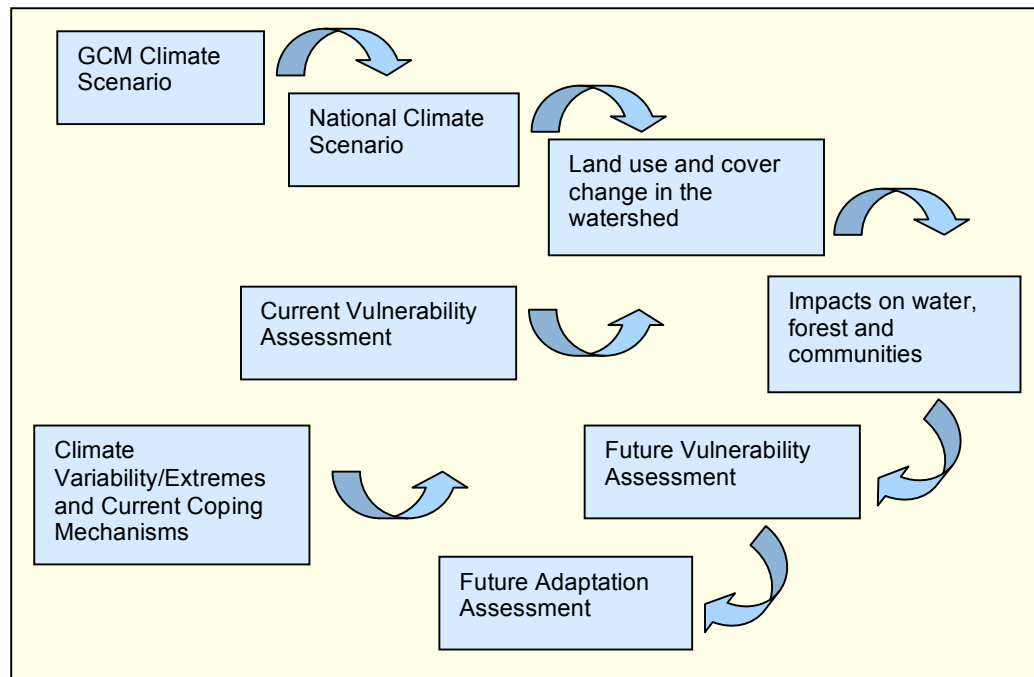
### ***Approach***

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. Characterize 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% and temperature by more than 5% of the average observed daily values between 1960 and 1990. This change in climate could translate into about 17% increase in the wet season streamflow and a decrease of around 35% in dry season streamflow of the PCW. The increase in streamflow could lead to 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% of the entire PCW is moderately vulnerable to climate extremes and change while more than 25% 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, drying 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% 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% 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. Additionally the downstream community is willing 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% 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 is the enhancement of capacity of local researchers to conduct climate change impact and vulnerability assessment. By working with developed country scientists from its key partners, (ICRAF and GCTE) there were 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 are provided to stakeholders. Trainings in climate change impact assessment methods were conducted to capacitate local scientists and stakeholders. Research teams members also regularly present 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 2<sup>nd</sup> National Communication. One of the team members, Ms. Joycelline Goco heads the preparation of the 2<sup>nd</sup> 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 leading to the preparation of the 2<sup>nd</sup> National Communication. Many of the findings of the AS21 project, including climate projections and local adaptation strategies, are expected to provide direct inputs to the 2<sup>nd</sup> National Communication being pioneering studies in this area. These findings are expected to address 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 livelihoods 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 (Brook, 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 raising 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.

## 5.4 Vulnerability and Adaptation to Climate Variability and Change in Western China (AS 25)

### 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, 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 levels of a set of adaptation options through a 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).

### *Scientific findings*

Since its official beginning in August 2003 (the GEF Focal Point for China endorsed the AS25 project on August 25, 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 trend 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 0.2°C/10year (yr) to 0.4°C/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%/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 21<sup>st</sup> century was calculated by the NCC/IAP T63 (National Climate Center/Institute of Atmospheric Physics). 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 21<sup>st</sup> century, especially NW China, e.g. an increase in temperature anomalies for SRES scenarios by 1.0-2.5°C 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 3.5-6.5°C for A2 and 2.5-4.5°C for B2.
- Precipitation over most parts of West China, especially in NW China is likely to increase by about 5-30% for A2 and 5-25% 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 NW 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 0.4°C, 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%) under current climate conditions, far exceeding the critical threshold levels set by both WMO 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% (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 & 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 IA methods in a real world context (About twenty 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*, May 17-19, 2004, Lijiang, Yunnan Province, 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 NC in this project. Since the executing agencies and key experts responsible for China's NC are partners of the project (i.e. project Steering and Expert Committee leaders and members), the study results can make a useful contribution to China's NC. 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 submitted a concept paper entitled "Adaptation Actions to Reduce Water System Vulnerability to Climate Change in Heihe River Basin" to the ACCCA project for consideration. A successful pilot adaptation action plan 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. The follow up study will recommend steps in implementing effective adaptation measures in the region to enhance regional sustainability.

## 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 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 largely 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](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 Hidráulicos (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 this region with MAGICC and SCENGEN using as inputs, greenhouse gas (GHG) emissions (Alvarado et al, AIACC 2005). Scenarios were built for the following time horizons: short time 2010, 2020, 2030; mid time 2040, 2050; long time 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 (AIACC, 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, 2003). Flood and droughts are the main manifestations of extreme climate in Central America, causing close to 85% 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 determine 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 Niño 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.

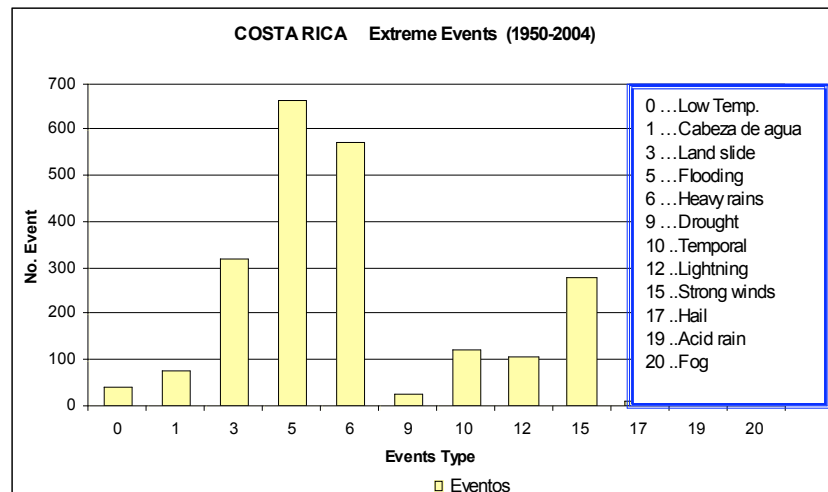
### ***Climate change scenarios***

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 change in temperature has the largest increases during the boreal summer (June-August) and the lowest 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 in 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 69 of the 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 lead to water resource conflicts in the future and calls for 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 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 Corporation (CORBANA), which was helpful in enabling work on this subject.

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 died 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 the impacts of 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 on 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 Climático,” 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.

The project LA06 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 at 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 (LA 26)**

### **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. 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 from the ocean of astronomic and storm surge tides 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.

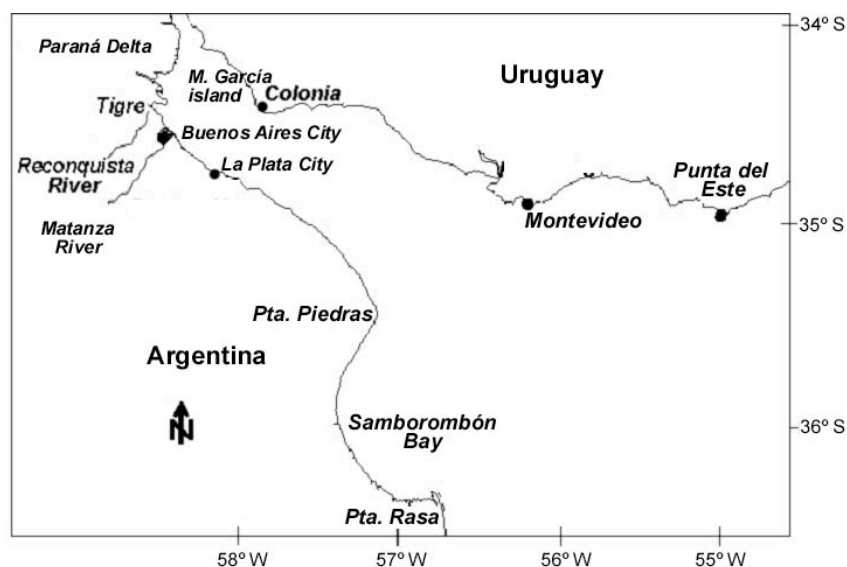


Figure 6.2: The Plata river estuary

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. In this context, 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, it was intended to estimate the number of people affected 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 (2001) 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<sup>2</sup>. 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 the 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 the risk of enduring floods during this century in 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 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 A2 SRES 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% 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 now 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 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 start 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 (LA 27)**

### **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 considered 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 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 (N of Buenos Aires, S of Santa Fe and SE 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 the proposed 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 sector 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 -HADG).

### ***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°C higher than in 1930 (range: 1.5 to 12.3°C). The absolute minimum temperatures increased an average of 1.9°C (range: 0.9 to 3.5°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 HADC. Both methods projected increases in minimum temperatures, but opposite results in maximum temperatures (LARS projected decreased values in summer and no changes in the rest of the year, and HADCD 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 allow crops to benefit from the expected increase in rainfall during the maize and soybean growing season and the expected direct CO<sub>2</sub> 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<sub>2</sub> environment and the climatic conditions projected for HadCM3 for 2020, 2050 and 2080 for SRES A2 and B2 scenarios. However, crop responses to CO<sub>2</sub> enrichment under field conditions are yet to be 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<sub>2</sub> on crops in the long term are still uncertain. Research over the last few years has suggested that the initial stimulation of photosynthesis observed when plants grow at elevated CO<sub>2</sub> 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 was greater under the climate change scenario than historically. The highest 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<sub>2</sub> concentration is considered, adaptive measures including optimal planting dates and nitrogen rates would result in maize mean yield increases of 14%, 23% and 31% for 2020, 2050 and 2080 respectively under SRES A2, and 11%, 15% and 21% respectively, over the same period, under SRES B2. The corresponding figures for mean soybean yields were: 35%, 52% and 63% for 2020, 2050 and 2080 respectively under SRES A2, and 24%, 38% and 47% respectively, over the same period under SRES B2.

In the case of current CO<sub>2</sub> 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% under all scenarios. Soybean yields, in the absence of any adaptation measures decreased under all scenarios (1-12%). Changing planting dates led to a weak increase in yields (2-9%) only for 2020 and 2050. The addition of supplementary irrigation strongly reverted this situation increasing soybean yields between 30% (A2 2080) and 43% (A2 2020). Thus, rather simple adaptation measures could be beneficial for soybeans, even if CO<sub>2</sub> 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%.
- Differences in optimal planting dates between El Niño and warm SAO years can be attributed to differences in rainfall distribution.

The results of this research 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, with 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 10<sup>th</sup> 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:**

- 1<sup>st</sup> National Workshop AIACC, INIA Tacuarembó, Tacuarembó, 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.
- 2<sup>nd</sup> 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:**

- 1<sup>st</sup> 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, Interlink Sur Biotechnologies.
- 2<sup>nd</sup> 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:**

- 1<sup>st</sup> 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 have noted this uncertainty.

### *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 continue to put at risk the sustainability of the agricultural systems. Soybean is a high nutrient extractive crop with 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 the natural resources such as adequate crop rotations (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 (LA 29).**

### **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 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 were 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 data 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 (SCENGEM) 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*

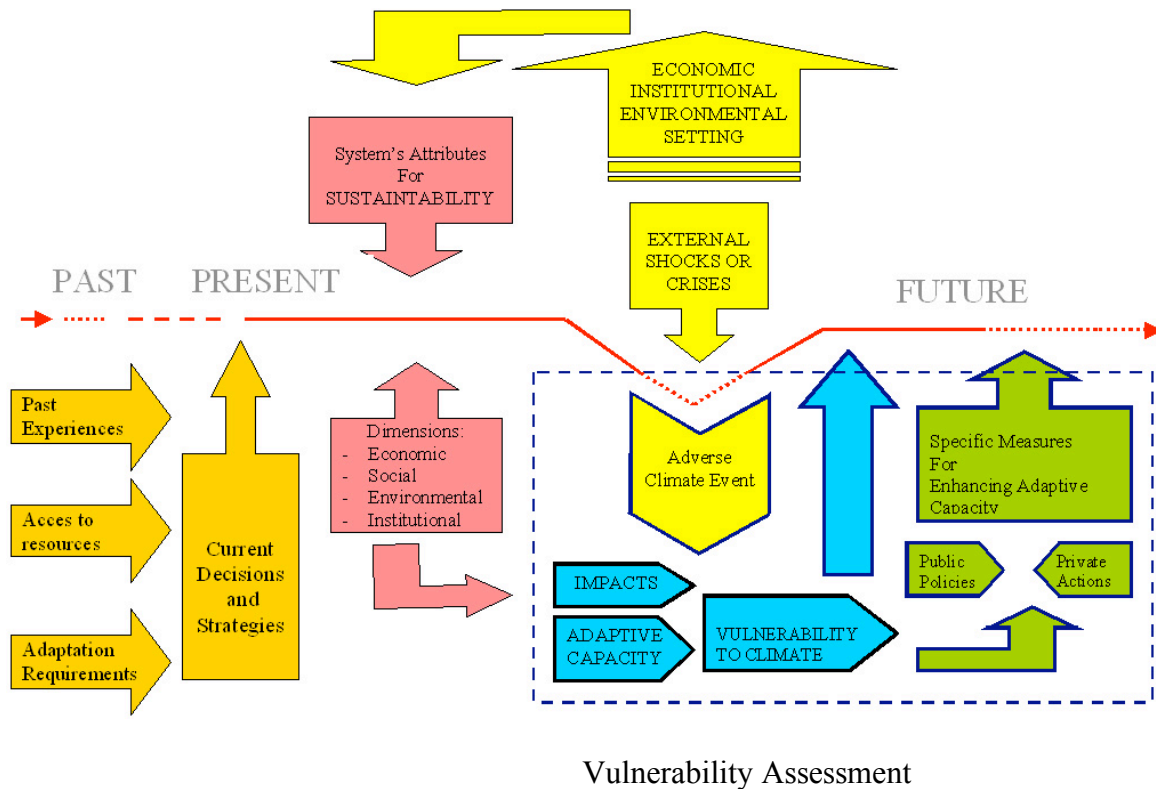
A political-ecology approach was adopted and the physical and social environments were assumed to be dynamic, evolving and highly uncertain contexts in which farmers make strategic decisions about their livelihoods (Scoones, 1999). The policy and institutional contexts of the agricultural sectors of 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 red line. The boxes in dark yellow represent the factors affecting the decision-making at the household-level. The light yellow area above the red line represents 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).

The light yellow 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 the 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.

## THE PROCESS OF SUSTAINABILITY



*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, 2005). 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, 2005). 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, 2005), 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 of 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.

No researchers in the social area (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; and 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 UNFCCC in Argentina since the centre of Argentina (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<sub>2</sub> 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 to continue 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 (LA 32)

### 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 (2001), referred to as TAR, identified two main environmental problems in South America: Land Use Changes and ENSO variability. The Río de la Plata basin (RPB) and estuary (RP) 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% since 1961 with the consequent increase in river flow ( $Q_v$ ) and decrease in salinity (Nagy *et al.* 1997, 2002).

The natural vulnerability of the RP 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 (EF) processes such as nutrient removal, in situ production of organic matter (CH<sub>2</sub>O), and denitrification are estimated to be high (Nagy, 2000). The main symptoms of eutrophication are an increase of organic matter (CH<sub>2</sub>O) "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, 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 RP 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 (TSC) and sea-level rise (SLR) in the Santa Lucia river lower basin and estuary (SLRE). 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.

### Overall framework for vulnerability and adaptation

The overall framework of this research is the second generation assessment presented in the figure below (Leary and Beresford, 2006).

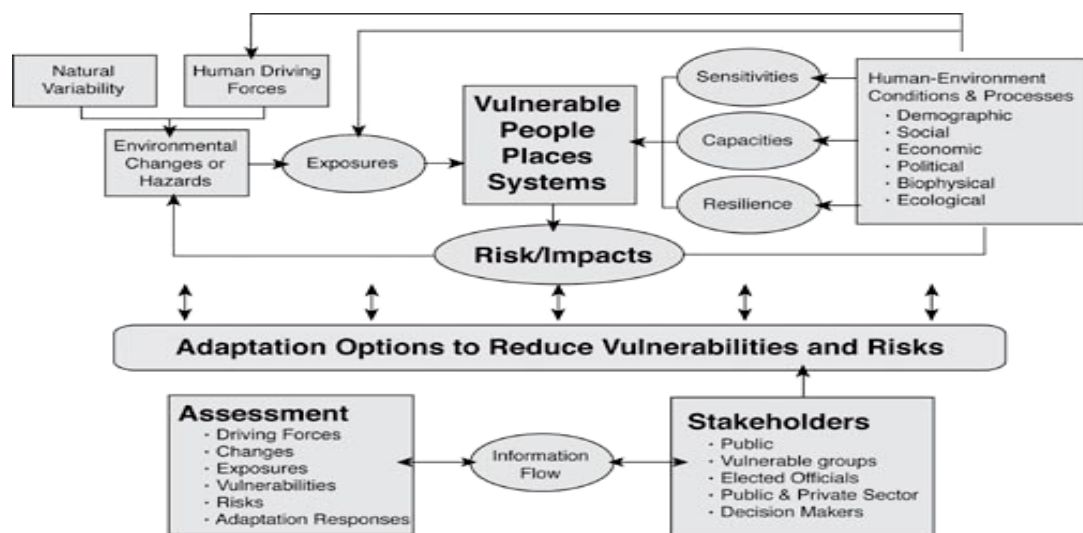


Figure 6.4: Vulnerability, Adaptation and Responses: Assessments (from Leary and Beresford, 2006).

## Scientific findings and questions

Main climatic changes in the RPB are the increase in ENSO variability and precipitation ( $\geq 20\%$ ), southward displacement of the Atlantic subtropical high pressure circulation-SAHP and changes in frequencies of the prevailing winds; increase in air and water temperatures ( $\geq 0.8^\circ\text{C}$ ), 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.*, 2004; Liebmann *et al.*, 2004).

### Climate Trends

We have updated climate, hydrologic and oceanographic yearly long-term trends up to 2000 / 2003 (temperature, precipitation, sea level pressure, river flows, sea level rise, salinity).

## *Coastal Fishery System*

Goal: To assess overall vulnerability of the Coastal Fishery System (CFS) in the Estuarine Front of the Rio de la Plata to cope with Global Environmental Change.

Problem: An artisanal fleet exploits fisheries a few miles off the Uruguayan coast in the estuarine front (EF) 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-SLR (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 (TSCs). Fluctuations in river flow thus induce environmental changes within the system and in the adjacent coastal waters of the EF of the RP.

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 (SLP) 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 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.

Some conjectures about plausible climatic and environmental scenarios: Current environmental scenarios (1971-2003) in the Rio de la Plata basin (RPB) 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 RPB and estuary suggest a change in precipitation, temperature and sea-level rise in the ranges +5% to +20%, +1 to +2°C and 10-15 cm respectively, whereas during the last few decades these changes have been + 20 to 25% for precipitation, +0.5 to +0.8°C for temperature, 5 cm for SLR, as well as + 25 to 40% 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%, 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 induce 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, vulnerability and adaptation assessment methods, GIS and Environmental Monitoring, Estuarine Systems, Remote Sensing, Global Environmental Change and Participatory 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) Participatory 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 3rd 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 2<sup>nd</sup> 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 nominated 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 Ministry 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 (Unit of Climate Change of the Ministry of the Environment in order to plan the Third National Communication).
- 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 3<sup>rd</sup> National Communication (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 ONGs, journalists and congressmen.

## 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, which are among the most vulnerable on this planet. 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](http://www.aiaccproject.org/Final%20Reports/final_reports.html)

### 7.1 The Threat of Dengue Fever in the Caribbean: Impacts and Adaptation (SIS 06)

#### 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 due to climate change, with 2.5 billion 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 levels of severity of DHF and the local concurrent circulation of all 4 dengue fever serotypes, as illustrated in Figure 7.1.

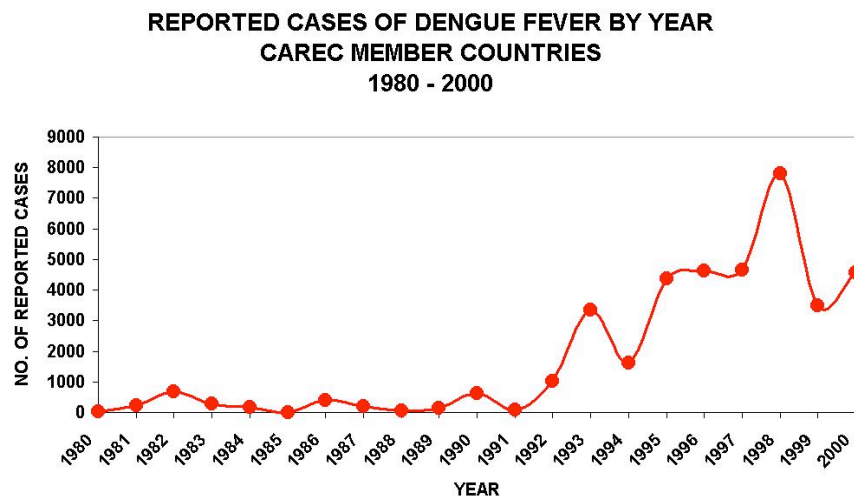


Figure 7.1: Number of reported cases of dengue fever in CAREC countries from 1980 - 2000

Dengue haemorrhagic fever (DHF) and dengue shock syndrome (DSS) have been demonstrated as being the most vicious form of the disease in the Americas. Dengue outbreaks would 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% and 53% of GNP in Antigua and the Bahamas respectively, and more than 10% 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, proliferation of water containers like discarded automobile tires and other non-biodegradable containers. Climate factors also play a role and transmission rate of dengue fever could increase with temperature (Hales et al, 1996) 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). Temperature increases and available stagnant waters in pools on the ground or in cans / tanks/ discarded containers provide a breeding ground and are considered likely responsible for dengue upsurges in the ENSO years and the El Niño +1 years (Poveda et al, 2000, Taylor 1999 and Chen and Taylor, 2001). Peaks in the incidence of dengue in the Caribbean in the El Niño years 1982, 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. Climate change related projected temperature increases of about 2°C for atmospheric CO<sub>2</sub> doubling and no change in precipitation (Santer, 2001) coupled with known El Niño induced temperature increases, could result in increased vector abundance and dengue fever 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 most effective in producing 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 and 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 *Ae aegypti* (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 up 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](http://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 2° C 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. An early warning system to predict the potential for the onset of dengue was therefore 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.

Adaptation strategies, including the early warning system, 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.

### ***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 the 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 the two 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 Communication of other islands. This project has laid the foundation for providing the basic inputs for decision making. It is assumed that collaborative research on climate change will continue though this project is over, 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 relevance of the project to decision makers, two workshops were held in Trinidad and Jamaica at the end of the project to outline the results of the project and their potential for 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 to all stakeholders, including those who attended the workshops 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.<sup>2</sup> 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), a software tool in support of training in V&A assessment.<sup>3</sup> 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).<sup>4</sup> These “first-order” models contain a

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<sup>2</sup> These models were built from the software components and tools developed exclusively for CLIMPACTS, an integrated model system for New Zealand, with funding from the New Zealand Government (Warrick *et al.*, 2001; Kenny *et al.*, 2000). Various other country applications had been developed from this foundation of work in New Zealand, including a model for Bangladesh (BDCLIM; Warrick *et al.*, 1996), Australia (OzCLIM), and a training software package for UNITAR (VANDACLIM; Warrick *et al.*, 1999a, b).

<sup>3</sup> Warrick *et al.* (1999). This training model has been also been used for training in small island developing states of the Caribbean and Indian Oceans, as well as in the Pacific island region where it continues to serve as the basis for a V&A assessment course offered each year at the University of the South Pacific.

<sup>4</sup> Within the framework of the PACific Islands Climate Change Impacts Model system (PACCLIM; IGCI, 1999). The acronym “PACCLIM” refers both to a sub-regional scenario generator to which each island-specific integrated model can, optionally, be attached, and, more generally, to the “umbrella” under which the modeling work has been conducted. As a regional scenario generator, PACCLIM simply offers a capacity for an island country to create and view climate change scenarios in their regional context; in this regard, it is similar in concept to other regional scenario generators like SCENGEN (Hulme *et al.*, 2000). However, in its broader “umbrella” function, PACCLIM, unlike other regional climate models or scenario

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,<sup>5</sup> provided support for further development of these models, especially for Fiji.

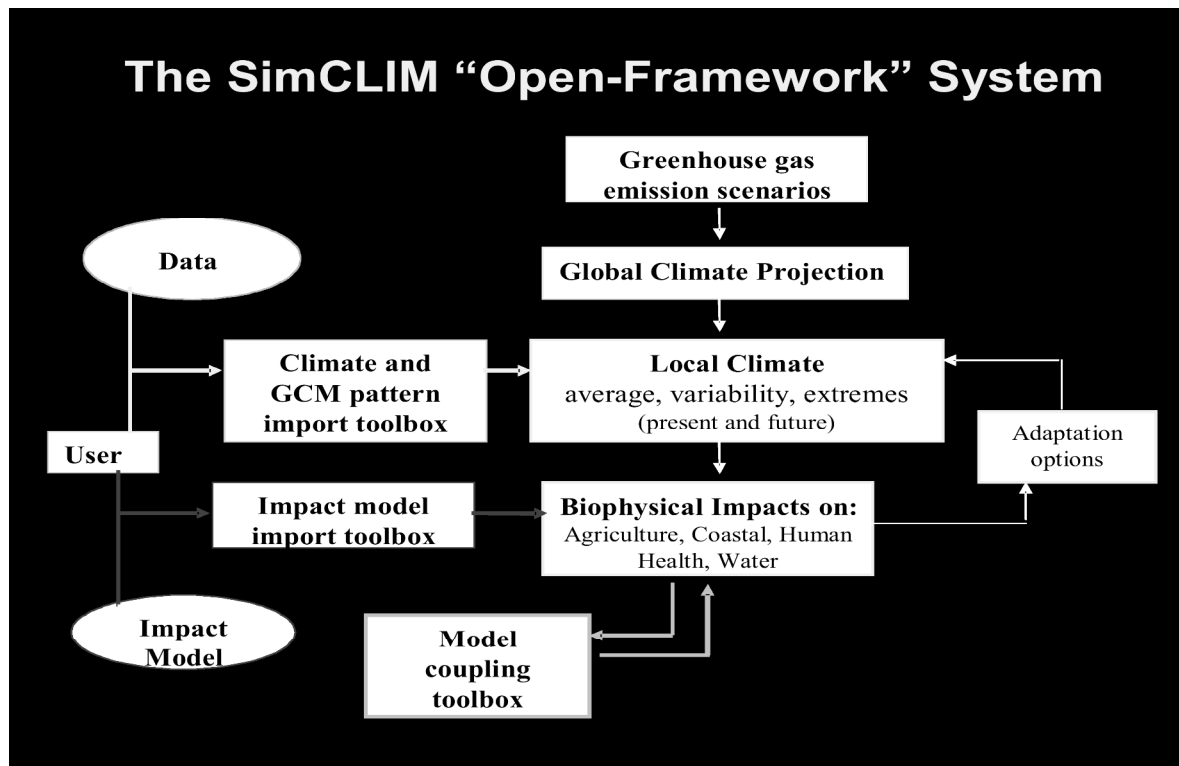


Figure 7.2: SimCLIM “Open-Framework” system (adapted from Warrick et al., 2005)

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 an opportunity for the SIS09 research team to combine the bio-physical impacts with the human dimension (see Figure 1) and develop the “next generation model” for integrated assessment (SimCLIM<sup>6</sup>) based on recent advances in

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generators, serves to link explicitly to island-scale models for purposes of V&A assessment. Thus, the PACCLIM system integrates from global to local.

<sup>5</sup> The integrated assessments for the two case studies are: Capacity-Building Activities Related to Climate Change Vulnerability and Adaptation Assessment and Economic Valuation for FIJI (2000); and Capacity-Building Activities Related to Climate Change Vulnerability and Adaptation Assessment and Economic Valuation for Kiribati (2000). These provided the technical basis for the World Bank’s Regional Economic Report (RER) report (World Bank, 2000).

<sup>6</sup> SimCLIM is the generic name applied to a software modeling system developed by the International Global Change Institute (IGCI, University of Waikato, New Zealand) for examining the impacts and

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.

## ***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, 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.

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adaptations to climate variability and change. The distinctive advantage of the open system, as opposed to the hard-wired system, is the flexibility afforded to users for importing their own data and models in order to customise the system for their own purposes – much like a GIS (Warrick *et al.*, 2005). As indicated in Figure 1, there are tools to allow the user to import: (1) spatially-interpolated climatologies and other spatial data (e.g. elevation surfaces); (2) site time-series data; (3) patterns of climate and sea-level changes from General Circulation Models (GCMs); and (4) impact models that are driven by climate (and other) variables. The geographical size is a matter of user choice (from global to local), as is the spatial resolution (subject to computational demands and data availability).

## 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 through 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: time-horizon, discount rate for adaptation measures and (v) the model's capacity to be used for coastal inundation, freshwater lens, health impact and shoreline change modeling.

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 oversight 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, 2001), 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 has been developed with the ability to implement this 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***

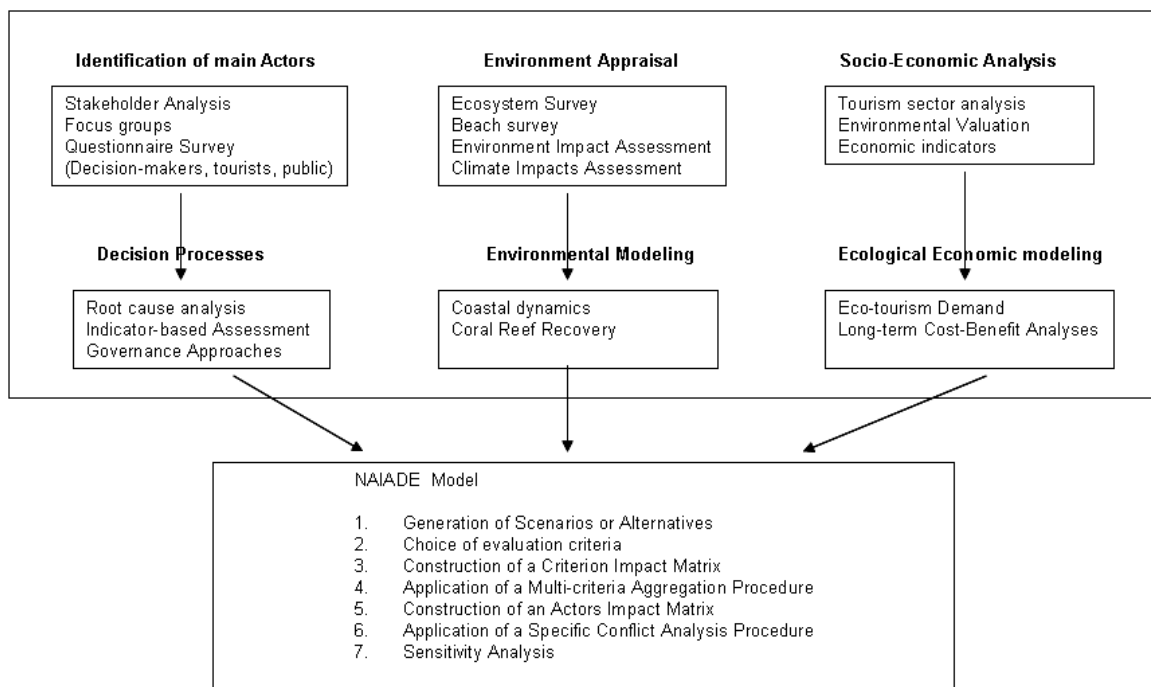
The impact of long-term climate change on tourism still remains unclear. Although several studies have been undertaken on understanding the relationship between climate change and tourism, an approach that considers the linkages between the resource base of tourism and its socio-economic aspects has not been adequately investigated for the small islands. Six tourism sites in Seychelles were therefore assessed 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 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 1, 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 (Payet, 2006) 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), Payet (2007) 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 (Sokal and Rohlf, 1995). 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 NAIAD (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 manage 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. It is observed that the dry season in Seychelles is becoming drier and the wet season wetter. Most models predict an increase in wet season ranging from -28.20% to +22.68%. 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% cover) (Wilkinson et al. 1999). 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 SST, 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 have serious implications 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 showed that climate change would have an impact on tourism demand in small island state destinations. Using a combination of statistical analysis of climate and tourist data and tourist surveys, the effects of temperature and precipitation were explored in detail. 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 of 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 (from another AIACC project) 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: 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 2<sup>nd</sup> National Communication and work that could not be completed under this research project will be further explored during the preparation of the second national communication. The 2<sup>nd</sup> National Communication 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 Fourth Climate 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.

## 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 is helping 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.

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 their work so as to be consistent with the inputs of others, 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 Workshops**

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 regional assessment teams themselves, and south-south training activities in which regional assessment teams provided training for other teams in the AIACC network.

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, IIED, 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](http://www.aiaccproject.org).

There are also several cases of collaborative south-south training activities that have been implemented by the AIACC regional assessment teams. For example, a project based at the University of Cape Town held a workshop on regional climate modeling in collaboration with the Hadley Centre. Scientists from the 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. An AIACC assessment based in Thailand provided training in hydrologic modeling to members of an AIACC assessment in the Philippines. In turn, the Philippines project has conducted training workshops for scientists in nearby LDCs: 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 carry out mini-assessments. A project administered by CSIR of South Africa implemented a training course on conservation of biodiversity in a changing climate for land and biodiversity managers from across Africa. The course is now being developed into a web-based course with the University of the Western Cape. 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.

### **8.3.1 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 would investigate vulnerabilities to climate change and climate variability within their regions, evaluate adaptation options, and engage 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.

The stage was set on the first day by four keynote talks on new directions in climate change assessment. Ian Burton, Michael Hulme, Richard Warrick and Tom Downing made presentations on, respectively, frameworks for assessing adaptation, development and application of climate and socioeconomic scenarios, integrating science and stakeholders in the assessment process, and vulnerability assessment frameworks and measures of vulnerability. Patrick Mushove, Patricia Romero, Yongyuan Yin, and Rodel Lasco added their comments on these topics and challenged the meeting participants to explore and advance innovative methods of assessment. Later in the week, additional presentations on advances in assessment methods were made by Mac Callaway, Max Campos, Bill Dougherty, Andrew Githeko, Saleemul Huq, Roger Jones, Kate Lonsdale, Xianfu Lu, Graciela Magrin, Anand Patwardhan, Bob Scholes, Cynthia Rosenzweig, and Mike Rutherford.

The presentations, and the discussions that followed, raised a number of issues that 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 struggled with 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. For many of the study teams, the meeting in Nairobi was only the beginning of a process to refine their study objectives, methods, models and scenarios that would continue at upcoming AIACC workshops. Ultimately, each regional study would craft and implement its own approach.

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 will 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. The AIACC office, at that time, was exploring options to implement other suggestions made at the Nairobi meeting for training and technical support.

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 had begun planning joint activities. As a result of these discussions, plans were made for the AS07 study team based in Bangkok to provide training in hydrologic modeling tools to members of the AS21 study team from the Philippines.

With this very stimulating meeting, the AIACC regional studies were launched and participants looked forward with high expectations for good science that would be relevant to important problems and decisions.

### **8.3.2 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 non-climate futures, climate scenarios methods, hands-on practice with climate scenarios tools, and scenario design. The workshop largely focused on methods and tools for climate scenario design and application. To ensure that the most appropriate methods/tools are selected for individual projects, equal attention was paid to all the available techniques and tools, rather than promote a single or a set of preferred methods.

There were twenty-five participants, with 24 representing 23 AIACC projects and one person from a related project in South Asia that is funded by the Asia Pacific Network. Most of the participants had a background in geography or meteorology and were responsible for scenario development for their AIACC regional studies. Nineteen speakers were invited to cover topics ranging from overall methodological framework for Impacts, Adaptation & Vulnerability assessment, socio-economic futures, present day vulnerability assessments, to a variety of climate scenario methods and techniques.

The workshop kicked off with five presentations from selected participants followed by plenary presentations, discussions, and hands-on activities around the six workshop themes. Regional studies participants were provided with several opportunities to meet in small groups with AIACC mentors to discuss region- or sector-specific concerns and prepare for final-day presentations. The final day of the workshop consisted of presentations by participants from each region and a wrap-up discussion of lessons learned, immediate needs, and future directions.

Most participants came with clear expectations and practical questions. The initial presentations by regional studies participants on the first day of the workshop indicated a strong need for guidance and information on scenario development. Common obstacles faced by investigators include, among others, the shortage of observational climate records, lack of access to climate model outputs, and absence of adequate expertise to address the mismatch of temporal and spatial resolution between what climate models are able to provide and what is required by impacts, adaptation and vulnerability assessments.



At the end of the first week, Dr. Mike Hulme of the Tyndall Centre made a brief presentation on and led a discussion about the problems inherent in the creation of climate scenarios and the lessons learned from the first week. Problems encountered in the creation of climate scenarios included: the inaccuracy of climate models, the expense of running many global or regional climate model experiments for many future emissions scenarios, and that many climate models provide the results at a scale too coarse to be applied in impact assessments. Lessons learned during the first week of the workshop pertained to important issues regarding conducting case studies; scenario construction; integration of scenario information; quality of observed data; sensitivity studies; maintaining simplicity; and ability to work with a regional climate model (RCM):

The second week of the workshop was devoted to hands-on activities and scenario design. Participants from each region met during the second week to work on a revised version of scenario design strategies for their studies. Specifically the groups were asked to answer several questions in their presentation, pertaining to climatic data requirements, based on the new information they learned during the workshop:

On the final day of the workshop, the entire group met for the regional presentations and wrap-up discussion. Specifically, the regional presenters indicated the methodology they plan to use, their data needs (climatic and non-climatic), foreseen obstacles, uncertainties, and planned collaboration with other projects in their region (primarily within, although also outside of the AIACC network). There were several problems, needs and concerns that were shared by nearly all of the groups. These pertained to: 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.

These presentations were extremely useful for participants to guide their discussions and establish linkages within their regions. For example, the AIACC projects with activities in southeastern Latin America (LA26, LA27, LA29, LA32) decided as a result of their collaborative work at the workshop to share information and generate common scenarios for their region. By incorporating what was gained from the workshop, the final presentations suggested a marked increase in understanding the key issues regarding scenario development. On their way home, participants were better equipped with the knowledge of what is currently available, how to select the appropriate methods/techniques to use, how to represent uncertainties in scenarios, and of course, the technical and practical obstacles that remain to overcome in the months to come.

The groups also had several specific suggestions for future support from the AIACC community. Also important on the final day was the presence of Professor Martin Parry, Co-chair of Working Group II of the IPCC. Professor Parry provided valuable insights to the discussion, and also underlined the importance of publishing outputs from these projects by 2005 in order for the research to contribute to the IPCC Fourth Assessment Report.

A CD-ROM was produced to include all the course materials and additional recommended papers and materials to help the participants transfer what they learned from the course to a wider audience in their respective countries/regions.

Based on the evaluation of the course by participants, it was determined that people were generally happy with the workshop provisions and the majority of them indicated that the objectives of the workshop were largely attained. The major dissatisfaction expressed by participants is the fact that there was not enough time to allow them to practice with the models and tools in the IT lab. However the primary objective of the workshop was introducing a wide range of available scenario development methods and techniques and it was very hard to allow enough time during the workshop for participants to become confident users of a set of software. All the tools/models introduced at the workshop were made available to all the participants, along with the accompanying manuals and technical notes from the workshop. With these materials it would be possible for participants to gain a more thorough understanding of the models/tools after they go

back and eventually become advanced users of these packages. Xianfu Lu of the Tyndall Centre and AIACC mentors would be available to participants during implementation of the regional studies to provide further guidance in the use of any of the tools.

### **8.3.3 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. Many of the presentations made at the workshop were distributed to participants on CDs and are also available on the AIACC website ([http://www.start.org/Projects/AIACC\\_Project/aiacc.html](http://www.start.org/Projects/AIACC_Project/aiacc.html)).

Regional study teams were also able to consult one-on-one 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 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 the 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. Also, AIACC planned to soon develop an interactive web-resource to facilitate continued communication among study teams for sharing experiences, expertise, relevant publications, data, and results from their studies.

Regional study teams could also seek guidance from AIACC mentors to troubleshoot problems that arose during the project. The mentors could offer expert advice, review interim products of the studies 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 was in the process of seeking funding from potential donors.

It was agreed at the Trieste workshop that the AIACC regional study teams would play a large role in planning the regional workshops to be held in Africa, Asia and Latin America in early 2003 and late 2004. The objectives of the regional workshops were: (i) to encourage the preparation of scientific papers and provide opportunities for review of draft papers by peers; (ii) to facilitate collaboration and sharing of information, experiences and solutions to common problems across regional study teams; (iii) to engage with regional stakeholders, and (iv) to provide a mechanism for the synthesis of the AIACC regional studies along both regional and thematic lines.

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 general satisfaction with the workshop largely with respect to the attainment of objectives, appropriateness of the workshop design, the quality and usefulness of most course modules, and the content of plenary presentations. However, there were some issues that arose during the workshop. Some participants felt that the hands-on training with models for assessing impacts, vulnerabilities and adaptation was insufficient; some felt that the training with models was too rudimentary ; while others 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.

## **8.4 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](http://www.aiaccproject.org).

### **8.4.1 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 Hartbeespoortdam, 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
- 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.

Small 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.

#### **8.4.2 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.

#### **8.4.3 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 attending 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 (FUNDECOPERACION\_GEF) 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 Principal Investigator at the University of Costa Rica.

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 2<sup>nd</sup> Phase

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 Fernandes, 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 additional invited guests and stakeholders with a special interest in climate change issues in Latin America and the Caribbean.

#### **8.4.4 Second AIACC Africa Region Open Meeting and Workshop**

##### **Dakar, Senegal, 24-27 March 2004**

The 2<sup>nd</sup> 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 Supérieure 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](http://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 Supérieure 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 this 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 the following topics:

- Climate Change Impacts & Vulnerability
- Climate Variability, Changes and Scenarios
- Socioeconomic Scenarios
- Adaptation Opportunities and Decision-Making
- Climate Change and the Development Agenda
- 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 Integration of Adaptation into Development Policies.

Stakeholders were invited to present on their interaction and reaction to the regional study activities to support a discussion 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. Some of the important messages that emerged from the presentation and discussions at the workshop are outlined below:

- Adaptation
  - Adaptation is needed now
  - Adaptation is best approached as a continuous process
  - Adaptation to climate change should be mainstreamed
- Vulnerability
  - 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
  - Place-based regional case studies in Africa are filling critical gaps in knowledge about climate change vulnerability and adaptation
- Climate change scenarios for Africa
  - Significant progress has been made in developing scenarios of climate change for Africa and adding capacity for climate science research in the region
- Engagement with stakeholders
  - The value of climate change research and assessment for policy application is greatly enhanced by meaningful engagement of stakeholders
- Investments in knowledge and capacity
  - Investments in scientific knowledge and capacity related to climate change yield high payoffs in the developing world

Stakeholders also made recommendations for a better 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.

### **8.4.5 Second AIACC Latin America and Caribbean Regional Workshop**

#### **Buenos Aires, Argentina, 24-27 August 2004**

The 2<sup>nd</sup> 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 report was distributed at COP-10 in Buenos Aires and is available at [www.aiaccproject.org](http://www.aiaccproject.org).

The workshop was attended by 84 persons. Principal investigators and local representatives 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 the United Nations Environment Programme and the United Nations Framework Convention on Climate Change 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; and
- AIACC is filling important needs for advancing knowledge, capacity and networks that complement other efforts in Latin America and the Caribbean



## **8.4.6 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 co-chairs, Rodel Lasco and Neil Leary. This was followed by addresses by 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 upon the importance of the AIACC project for the Filipino farming community, which is highly vulnerable to changes in climate; 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) – START's partner organization in executing the AIACC projects, 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.

## **8.5 Supplemental Grant Program for Capacity Building and Stakeholder Participation**

The training and regional 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 capacity needs that could not be adequately addressed by the large training workshops. In addition, during their implementation of their assessments, many of the regional projects came to see stakeholder engagement as a valuable aspect of their work that they wanted to expand. To address these needs, 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 US\$298,176 of which \$130,336 was funded from the USAID grant and \$167,840 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 (see Table 1). Evidence of the capabilities and their application is provided by 15 papers published by AIACC

participants in peer-reviewed journals and 20 more working papers that are in review. Further evidence will be provided by the technical reports on vulnerability and adaptation to be produced by each project in 2005. The grants contributed to building relationships among scientists and scientific institutions for ongoing research and assessment of climatic risks and response options. Each of the grants brought together persons from multiple disciplines and multiple institutions, and often from multiple countries, to focus on research that is targeted to decision making. The grants also brought together stakeholders with researchers with the result that the research is better targeted to decision-making needs, there is a shared understanding of climate risks and response options among stakeholders and researchers, and important groundwork has been laid for the use of research outputs in decision making to manage climate risks and adapt to climate change. The partnerships have included stakeholders from local community organizations, farmer organizations, government agencies from local to national levels, and private sector organizations. These partnerships that link together scientific, public sector, private sector and civil society organizations are an important legacy of the AIACC project and the supplemental grants program that can facilitate sustainable responses to climate risks.

Summarized here is a sample of the activities and accomplishments supported by the small grants program.

- Climate modeling and scenarios in Africa: Grants to University of Cape Town, South Africa, and University of Cheikh Anta Diop de Dakar, Senegal, trained 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 was assisted in applying the model to simulate the impacts of climate change on water balances and crop yields. GCRU is now using the modeling framework to perform similar analyses to feed into their work on the evaluation of benefits and costs of climate change adaptation policies. The other Gambian agencies are applying the modeling framework for seasonal projections to be used in management planning.
- Conserving biodiversity in a changing climate: CSIRO, South Africa, is using its research results 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. Training materials and program have been developed for a training workshop for land management officials. Officials from 10 African countries will attend the workshop, scheduled for February 2005.
- 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 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. The collected data is being analyzed to understand the impacts of climate variability on rice farming in the basin, potential climate change impacts, and possible adaptations. Workshops will be held to share results with the community leaders and government officials, get their feedback, and explore adaptation strategies.
- Climate risks in the Rio de la Plata basin: The University of Buenos Aires and Universidad de la Republica 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 is being used to revise the two documents, which will then be 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.

## 8.6 International 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. Multi-country projects have resulted in important inter-country collaborations, for example among Kenya, Uganda and Tanzania; Mozambique, Malawi and Zambia; Egypt and Tunisia; Thailand, Cambodia, Lao PDR and Vietnam; and Argentina and Uruguay.

Important connections among international organizations are also being 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 4<sup>th</sup> 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 4<sup>th</sup> 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, and the Chinese Academy of Sciences, expert meetings of SBSTA and IPCC, and side events at UNFCCC Conference of the Parties. AIACC participants have 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, project implementation committee 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.

## 9 Project Outputs and their Use

The major outputs of the project include regional climate change assessments, capacity building, networking and scientific publications. 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. 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 United Nations Framework Convention on Climate Change (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 4<sup>th</sup> 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. Some examples of the uses of the climate change assessments are described below. Additional details and examples can be found in the summaries of the climate change assessments presented in chapters 4 through 7, as well as in the full reports from each assessment.

Examples of uses of the AIACC climate change 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 4<sup>th</sup> 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 4<sup>th</sup> 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 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 4<sup>th</sup> 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 4<sup>th</sup> 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. Findings from the malaria-cholera project are included in the IPCC 4<sup>th</sup> Assessment report.

- The PI 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 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.
- 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 4<sup>th</sup> 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 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) will be 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 Capacity Building and Networking

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.

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, work with peers on synthesis for 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.

The primary use of the capacity built by the project is in the execution of the AIACC climate change assessments. 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. Another important application of the enhanced capacity is in preparations of national communications to the UNFCCC, which are benefiting from and using the advanced knowledge base and the enhanced assessment and synthesis capabilities of the AIACC teams. The previous section gave some examples of applications of the enhanced capacity to national communications and additional examples are documented in Chapters 4 through 7.

The enhanced skills and knowledge of the AIACC teams are being applied to the IPCC's 4<sup>th</sup> 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 Publications**

The output of scientific publications from the AIACC project is substantial and exceeds what is achieved by comparable projects. As of the time of the writing of this report, peer-reviewed publications from the AIACC project numbered 99, 55 in peer-reviewed journals and books and 44 in the peer-reviewed *AIACC Working Papers* series (see <http://www.aiaccproject.org>). In addition, two books from the project, *Vulnerability to Climate Change* and *Adaptation to Climate Change*, 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. Also, more than 50 other publications that are not peer-reviewed were produced by the projects and 25 student theses were completed with support from AIACC. The final 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 102 citations to AIACC publications in the new IPCC Working Group II 4<sup>th</sup> 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.

The 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 and present measures of progress achieved by the AIACC project.

### 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](http://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 150 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 102 citations to AIACC publications in the IPCC Working Group II 4<sup>th</sup> Assessment Report. Publication in peer-reviewed literature and citation of many of the papers in the new IPCC 4<sup>th</sup> 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](http://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 4<sup>th</sup> 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), 2<sup>nd</sup> International Workshop on Climatic Prediction and Agriculture (Switzerland, May 2005), 16<sup>th</sup> Global Warming International Conference (New York, 2005), the International Conference on Stabilizing Greenhouse Gases (Hadley Center, UK, February 2005), 14<sup>th</sup> 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 4<sup>th</sup> 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 excellence 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 Philippines 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 adaptation 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 150 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](http://www.aiaccproject.org).

**Indicator 2.2:** Citation of publications in scientific literature

Performance: There are 102 citations to AIACC publications in the IPCC Working Group II 4<sup>th</sup> Assessment Report.

Source: IPCC draft chapters.

**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](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 Science orientation and merit based awards**

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 upon 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. This approach gave greater access to the science community, and to a broader range of science institutions, than is often the case in GEF projects. 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 taxing at times, 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 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.

### **11.2 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, sharing of methods, sharing of expertise, sharing of data and sharing of 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 technical advisors who provided assistance tailored to the individual teams. It was also 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.

### **11.3 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.

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 3<sup>rd</sup> 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. Many of the Technical Committee members had played a role in recognizing the need for advancing scientific knowledge and capacity of developing countries and in organizing the science community to call for and develop a proposal to the GEF for the AIACC 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.

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 by the AIACC project. The tasks of monitoring performance, providing technical assistance and training, organizing workshops (including travel arrangements), 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.

### **11.4 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, paid for in part with new funding provided by USAID, 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 though is needed. 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 little resources to expanding scientific knowledge and building scientific capacity. Science funding agencies, while providing some support for science in developing countries, have generally considered this to be the responsibility of development assistance agencies. 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

## 1 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.

### 1.1 Peer Reviewed Publications

#### 1.1.1 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. Leary, N., C. Conde, A. Nyong and J. Pulhin (eds). 2007 (forthcoming). *Vulnerability to Climate Change*. Earthscan, London, UK. (A collection of papers from the AIACC regional assessments).
3. Leary, N., J. Adejuwon, V. Barros, I. Burton, R. Lasco (eds). 2007 (forthcoming). *Adaptation to Climate Change*. Earthscan, London, UK. (A collection of papers from the AIACC regional assessments).
4. 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).
5. 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).
6. 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).
7. 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).
8. 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).
9. 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).
10. Wijeratne, M.A., J. Ratnasiri, and E.W.T.P. Premathunga. 2007. Effect of CO<sub>2</sub> 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).
11. 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)

### 1.1.2 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*. Obafemi Awolowo University Press, Ile-Ife 270 pp. (AIACC Project No. AF23)
4. Chadee, D. D., B. Shivanuth, 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. Matak, 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. Waidyaratne, 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)

### 1.1.3 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 20<sup>th</sup> century attribution of drying trends in the Sahel from the Regional Climate Model (RegCM3). *Geophysical Research Letters*, 32. (AIACC Project No. AF20)
9. Kanga, 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 21<sup>st</sup> 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. Kluivitskin, 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)

#### 1.1.4 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 developement 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)

### 1.1.5 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 índice 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)

### 1.1.6 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.

The papers are available at: [http://www.aiaccproject.org/working\\_papers/working\\_papers.html](http://www.aiaccproject.org/working_papers/working_papers.html).

- 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)
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### 1.3 Student Theses Supported by AIACC

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## 1.4 Final Reports from AIACC Regional Assessments

Final reports from the AIACC project are available at:

[http://www.aiaccproject.org/FinalReports/final\\_reports.html](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 Coastal 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

## 1.5 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.

1<sup>st</sup> AIACC Asia Pacific Region Open Meeting and Workshop, Bangkok, Thailand, 24-27 March 2003.

1<sup>st</sup> 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.

## 1.6 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 Stitch 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: 1<sup>st</sup> 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

## 1 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 Développement  
(IRD)  
Laboratoire de Physique de l'Atmosphère  
Simeon Fongang, Université Cheikh Anta Diop  
Service Météorologique

## **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  
Chiangmai University  
Mahidol 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 Oceanographic 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)

## Annex C

### 1 Inventory of Non-Expendable Equipment Purchased Against the AIACC Project

(Items US \$1,500 Unit Value and Above)

PROJECT NUMBER: GF/2010-01-07  
 PROJECT TITLE: Assessments of Impacts and Adaptation to Climate Change in Multiple Regions and Sectors (AIACC)  
 IMPLEMENTING AGENCY: Global System for Analysis, Research and Training (START); Third World Academy of Sciences (TWAS)  
 INTERNAL/SO/CA (UNEP): \_\_\_\_\_  
 FPMO (UNEP): \_\_\_\_\_

*(As reported by AIACC Regional Studies as of 15 April 2007)*

Description	Serial No.	Date of Purchase	Original Price (US\$)	Present Condition	Location
*Sony VAIO laptop (Neil Leary)		01 Sept 2005	2,688.44	Good	International START Secretariat
*PowerMac G4-867 MHz Computer (Neil Leary)	XB1311D2KSK	25 Sept 2001	2,402	Good	International START Secretariat
*PowerMac G4-867 MHz Computer (Neil Leary)	XB1341E9KSK	25 Sept 2001	2,402	Good	International START Secretariat
1 server Biprocessor 1GHZ (Amadou Gaye AF20)		18 June 2002	2,000	Good	LPA/Dakar
5 Personal Computers (Amadou Gaye AF20)		18 June 2002	3,870	Good	LPA/Dakar
Lap Top Computer (James Adejuwon AF23)	42872721	June 2002	2,388	Good	Dept of Geography, (Obafemi Awolowo University, Nigeria)
Projector (James Adejuwon AF23)	G1201088	June 2002	3,134	Good	Dept of Geography, (Obafemi Awolowo University, Nigeria)
Dimension 8200 Pentium 4 Dell PC (Paul Desanker AF38)	461-4485	21 Mar 2002	1,293.63	Good	Charlottesville, Virginia

Dimension 8200 Pentium 4 Dell PC (Paul Desanker AF38)	220-8138	21 Mar 2002	1,293.63	Good	Charlottesville, Virginia
Computer DELL 80 GB (Janaka Ratnasiri AS12)	J4YB61S	19 June 2002	1,650	Good	CRI
Computer DELL 80 GB (Janaka Ratnasiri AS12)	15YB61S	19 June 2002	1,650	Good	NRMS Ltd.
Computer DELL 120 GB (Janaka Ratnasiri AS12)	CYXB61S	19 June 2002	2,130	Good	TRI
Computer DELL 120 GB (Janaka Ratnasiri AS12)	DYXB61S	19 June 2002	2,130	Good	Met Dept.
CPU: Intel Pentium 4 2.0 GHz Computer (Rodel Lasco AS21)	L208A854	25 June 2002	1,700	Good	UPLB, College, Philippines
Toshiba /Lap Top /T8200 Model No. PT820E-01EQP-EN (Nagmeldin Goutbi/Balgis Osman AF14)	31181121G ST820-0	Oct 2002	2,000	Brand New	HCENR
3 laptop computers (COMPAQ) (Bubu Jallow AF47)	02-AIACC-01 02-AIACC-02 02-AIACC-03	22 Nov 2002	2,590.67 2,590.67 2,590.67	Good Good Good	Bubu P. Jallow Momodou Njie Bernard E. Gomez
4 Dell Computers (Shem Wandiga AF91)	55FRHOJ, 95FRHOJ, 28UBILM, 28UBILH	20 Dec 2002	5,846	Good	2 in Kenya (55FRHOJ, 95FRHOJ) and 2 in Tanzania (28UBILM, 28UBILH)
4 Printers (Shem Wandiga AF91)	CNCF529850, CNCF530024, CNCF529852, CNCF322521	20 Dec 2002	1,641	Good	2 in Kenya (CNCF529850, CNCF530024), 1 in Tanzania (CNCF529852) and 1 in Uganda (CNCF322521)
3 Fine Pix 401 x Cradle Camera (Shem Wandiga AF91)	31.2700298, 31.2770779, 31.2700293	8 Nov 2002	1,600	Good	1 each in Kenya (31.2700298), Uganda (31.2770779), and Tanzania (31.2700293)
Computer FOSA (Janaka Ratnasiri AS12)		20 Dec 2002	1,614	Good	TRI, Ratnapura

Computer FOSA (Janaka Ratnasiri AS12)	123000745	20 Dec 2002	1,667	New	TRI, Talawakelle
Computer FOSA (Janaka Ratnasiri AS12)	123000722	20 Dec 2002	1,667	New	CRI, Lunuwila
Computer FOSA (Janaka Ratnasiri AS12)	123000317	20 Dec 2002	1,667	New	Meteorology Dept. Colombo 07
Personal Computer: Toshiba 5233 PT: 1100; 256 MB; 40 GB; multimedia; fax 56k (Vicente Barros LA26)		19 July 2002	2,020	Good	Department of Physics, University of La Republica, Uruguay
Computer and laser Printer (Gustavo Nagy LA32)		3 July 2002	1,709	OK	Facultad de Ciencias – Seccion Oceanologia, Uruguay
Compaq Notebook (Pauline Dube AF42)	1V22KNVLH2RX	15 April 2002	1,636	Broken	Department of Environmental Science – University of Botswana
ProLine Laptop (Pauline Dube AF42)	22NP034477	13 November 2002	2,734	Stolen and replaced with Acer Travelmate by insurance	HOORC and Department of Environmental Science – University of Botswana
Epson LCD Projector: Model EMP-52 (Pauline Dube AF 42)	EXP0304688K	7 April 2003	3,133	New	Department of Environmental Science – University of Botswana
Delta-T Datalogger Model DL2e & Sensors(Pauline dube AF 42)	DL2e 191/7	16 September 2005	7912.52 (£4037.00 (UK Pounds))	New	Serule Field Site
Acer Travelmate Model C113TCi (Pauline Dube AF 42)	LXT270E303513007DD000	29 July 2005	1919.52	New (replaced stolen ProLine above)	Office of Research & Development UB
Dell Latitude D410 Laptop (Pauline Dube AF 42)	PIW632500516610	16 April 06	2110.00	New (replaced broken Compaq notebook)	Dept. of Environmental Science, UB
Computer (Anthony Chen SIS06)	AQ17HXAT105333M	6 February 2003	1,384	Good	CAREC

Dell Inspiron 8200, P4, 1.7 Ghz, 512MB CDR-W (Adebowale Adepetu AF92)	Cn-04h459-12961-2bb-7737	15 November 2002	2400	Very good	University of Jos, Nigeria
Dell Inspiron 8200, P4, 1.7 Ghz, 512MB CDR-W (Adebowale Adepetu AF92)	Cn-04t176-12961-2ap-6943	15 November 2002	2400	Very good	University of Jos, Nigeria
Compaq Notebook Computer (Abou Berthe AF92)		23 May 2003	2350	Very good	IER, Mali
Dell Inspiron 5100 Model Number PP07L Lap-Top Computer (Kanayathu Koshy SIS09)	2U913A02	22 July 2003	2,505	Ok	PACE-SD University of South Pacific Suva Fiji
2 laptop computers (Acer Tablet PC) (Ayman Abou-Hadid/Mahmoud Medany AF90)		16 September 2004	4,616.63	OK	Dokki, Egypt
1 Weather Hawk station, Ayman Abou-Hadid/Mahmoud Medany AF90)	MicroMetos	26 June 2005	2,053.14	Good	Dokki, Egypt
Computer (Mougou, AF90)	4550	April, 2003	1,986.85	Good	Tunisia
Computer (Mougou, AF90)	128157	March 2004	1,610.02	Good	
Computer (Mougou, AF90)	CZC4100456	May 2004	1,564.20	Good	
Laptop (Mougou, AF90)		September 2004	2,091.60	Good	
Laptop (Mougou, AF90)		October 2004	1,927.60	Good	
2X Toshiba Satellite Laptops (Rolph Payet, SIS 90)	25388350K	May 05	2,900	Working	Climate Centre
Colour Laser Printer (Rolph Payet, SIS 90)	CNGJ65506L	July 06	1,776	Working	Dept. of Environment

LG Laptop (Rolph Payet, SIS 90)	508KIHS213313	August 2006	2,355	Working	Dept. of Environment
Canon Video Camera (Rolph Payet, SIS 90)		August 2006	2,907.60	Working	Dept. of Environment
2 X Pentium Core 2 Duo Servers (Rolph Payet, SIS 90)	0609060J010010	Nov 2006	5,985.90	Working	Dept. of Environment
Pentium Celeron Computer (Rolph Payet, SIS 90)	0608PCS0140009	Nov 2006	2,200.00	Working	Dept. of Environment

Please note: with the exception of the items marked with an asterisk (\*), physical verification was done by the principal investigators of the regional studies. The name of the principal investigator and the AIACC project reference number is listed in parenthesis after the name of the item.



Physical verification of the items marked with an asterisk (\*) was done by Neil Leary:

Date: 16 April 2007

