The ADAPTATION CONTINUUM

Groundwork for the future

Editors: Tahia Devisscher, Geoff O'Brien, Phil O'Keefe, Ian Tellam

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This book represents the results of the Netherlands Climate Assistance Program (NCAP), which was implemented by ETC Foundation between 2003 and 2008 on behalf of the Directorate General for International Cooperation (DGIS) at the Netherlands Ministry of Foreign Affairs. From DGIS, support and guidance was given by Jaap Rooimans, Christine Pirenne and Paul Hassing,

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For more information please visit www.nlcap.net or www.weadapt.org.

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Note: *This is a collection of summary reports taken from the larger documents of the NCAP country teams. For reasons of consistency and conciseness any bibliographic material has been ommitted. Please see the full documents for references.*

Foreword

What is in a name or what is in a title? The short answer is that names and titles capture objects and by capturing the object give a sense of the direction of an argument. The title of this volume is no different and includes two key words that reflect on a unique effort. These two words are *continuum* and *groundwork*.

A continuum denotes a process which, in many ways, has no clear beginning or certain end. Adaptation is much like that. In everyday life, adaptation is occurring all of the time, but the specific adaptations referred to in this book, are people's responses to the reality of climate change. There is a sense in which mitigation can be seen as part of a broader adaptation and where adaptation itself can include both hard and soft technological interventions all the way through to a sophisticated approach of community based pre-disaster planning. Specific adaptation options will vary from place to place and country to country, significantly influenced by the availability of disposable income from livelihoods, insurance and governments' ability to finance infrastructure. Adaptation is complex and continuously evolving and hence cannot be resolved by a single answer. That is why the second name or title, groundwork, is significant.

People themselves, wherever they are, have to address the problem from where they see it. That is why the work of these 14 country teams in the Netherlands Climate Assistance Program (NCAP), contained in this volume, is so different whilst at the same time sharing a level of common methods. Groundwork is a necessary component to advance through the adaptation continuum. It is the worm's eye view of the world, not the bird's eye view. It emerges from the grassroots, in both local and science communities, to inform decision makers that the evidence suggests that there is no standard solution. The groundwork for the adaptation continuum is essentially a political message.

The challenge of the Netherlands Climate Assistance Program (NCAP) was to build upon and beyond the efforts of the Netherlands Climate Change Studies Assistance Program (NCCSAP). This latter program focused primarily on carbon emission counting and addressed issues of mitigation at a national scale for individual countries reporting to the United Nations Framework Convention on Climate Change (UNFCCC). Broadly speaking, adaptation addresses immediate threats, while mitigation addresses future threats. Present threats usually have a livelihood focus and an emphasis on current income, while future threats tend to be addressed by new technologies and large-scale capital expenditure. There were some early attempts at mitigation, but they were primarily driven from a biophysical perspective. The challenge was to drive adaptation from a human perspective, which requires a much more localized approach.

Within Adaptation Science, there is already a distinction between adaptation type 1 and adaptation type 2, where the former is adaptation work in developed countries on anticipated adaptation measures and the latter is largely occurring in developing countries, where the adaptation focus is much more on immediate needs.

A livelihoods approach captures what people want to achieve as a livelihood outcome, usually an increase in wellbeing and income, a reduction in vulnerability, improved food security, and a sustainable use of the natural resource base. This approach looks at changes in livelihood assets, defined as different capitals, namely human, social, natural, physical and financial. It does so by viewing the vulnerability context for livelihood asset creation outlining the shocks, trends and impacts of seasonality. It closely examines the structures and processes including government, private sector and civil society together with institutional settings, policies and law. But it is only a snapshot. To get a full picture, a more robust approach to adaptation would be a discussion of access to environment entitlements.

Central to an understanding of adaptation is the discussion on coping mechanisms, where coping mechanisms are the means by which people manage to survive difficult conditions. As people progressively adapt to stress, they will economize in the use of resources. Coping strategies are increasingly used by households as a result of exogenously induced factors, such as climate change, as well as endogenous factors such as death or debt within a household. Increasingly, the emphasis is on how coping mechanisms can help increase resilience, a notion which is best described as "bounce back ability".

Resilience in many ways is the opposite side of the coin to vulnerability. Vulnerability can be broadly defined as a degree of susceptibility to natural hazards, while a more broad definition would see it as the 'characteristics of a person or group in terms of their capacity to anticipate, cope with, resist, and recover from the impacts of a natural hazard'. Vulnerability is itself strongly correlated with poverty. In short, addressing vulnerabilities of livelihoods puts climate change into the poverty alleviation agenda.

By implication, these studies tend to be at the village or local level and employ a range of qualitative techniques as well as the more traditional quantitative techniques associated with social science surveys. But it is the combination of these techniques that allows the stories to be told by local people. There is a sense that the NCAP tried to capture the voices of the vulnerable.

Voices of the vulnerable are best captured by local people who are imbued with local culture. For this reason, the definition of research under the NCAP, the delivery of research outputs and the write up of the results was under the leadership and control of NCAP partners. ETC Foundation and the Stockholm Environment Institute (SEI) had a role to play in providing technical input and overall program management, but the essential ingredient for the success of the program was its local ownership.

In many ways, it is difficult to capture the wide range of methods and approaches, the broad sectors that were addressed and the strong conclusions generated by the studies, all of which bore a local flavor. This, of course has significant implications for trying to raise the issue of adaptation at a level of global environmental governance and even trying to address the adaptation challenge at a national level. What is clearly required is a robust participatory framework, in which people can organize to address present risk and where they understand that, with reference to future risk, they can access entitlements that enhance their livelihood provision. For them, the scholars from the Global South who did the substantive work, and the people with whom they did the research, the key issue in adaptation remains what they will be offered to address the significant impact of climate change on their livelihoods, a problem they did not generate but which they nevertheless have to bear.

Phil O'Keefe

Introduction

Ian Tellam, Phil O'Keefe

This book is a result of five years of work funded by the Netherlands Climate Assistance Program (NCAP). The focus of the program was to understand the challenges posed by climate change and climate variability on vulnerable groups and the policies needed to support climate adaptation in developing countries. The aim of the book is to share this experience in the hope that it will be helpful to those involved in shaping and implementing climate change policy.

The starting point for the fourteen NCAP studies included in this volume is the current vulnerability of people's livelihoods and how people are adapting. The impacts of climate change are very real, especially the impacts of climate variability. People are already adapting, although some of this adaptation works against long-term livelihood and ecological viability. The critical issue is how to build resilience into ongoing development, which itself can be negative because of the accumulative impact of adverse aspects of globalization, which narrows local opportunities. One key finding from this study is that adaptation is not an add-on but should be an integral part of development – a process we term the 'Adaptation Continuum' - discussed in more detail in the final chapter of this book. In the continuum a key concept is resilience, which is usually regarded as 'bounce-back' ability, but from a development perspective must be regarded as 'bounce-forward' ability.

The middle section of this book outlines the main findings and lessons learned by the teams in each of the fourteen countries that took part in the program. This first chapter sketches how the NCAP program grew over the five years between 2003 and 2008 into an international partnership of researchers and decision makers.

The United Nations Framework Convention on Climate Change (UNFCCC) was created in 1992 at the Earth Summit in Rio de Janeiro. Its objective is to stabilize atmospheric greenhouse gas concentrations at a level that will prevent dangerous climate change. This means that the main focus of the Convention is to reduce greenhouse gas emissions (*mitigation*), rather than to adapt to the impacts of climate change (*adaptation*). This reflects the general feeling among policy makers in the early nineties that climate change was mainly a problem that would become noticeable 50 or 100 years into the future.

In 2001, the body that provides scientific advice to governments negotiating under the Climate Convention – the Intergovernmental Panel on Climate Change (IPCC) – stated that there was new and stronger evidence that most of the warming observed over the previous 50 years had been attributable to human activities. At that point it became clear to policy makers that the climate was already changing. Moreover, it became clear that developing countries were already suffering increased storms, floods and droughts as a result of climate change.

The next round of international climate negotiations in Delhi, India, in 2002 took this new evidence on board. The Delhi Ministerial Declaration on Climate Change and Sustainable Development, for example, emphasized that adaptation should be a high priority for all countries but particularly for the Least Developed Countries (LDCs) and small island states. Thus adaptation gained equal status with mitigation. The adaptation agenda has moved on, and gained in importance, through Bali and now to Copenhagen. Adaptation is now an urgent global need.

Dutch development support to combat climate change was encouraged by the creation of the UNFCCC in 1992, the Kyoto Protocol in 1997 and the formulation of the Millennium Development Goals (MDGs). At the beginning of the 1990s a number of developing countries began to cooperate with the Netherlands on climate change related research. This resulted in the Netherlands Climate Change Studies Assistance Program (NCCSAP), which was executed by the Institute for Environmental Studies (IVM) of the Free University in Amsterdam between 1996 and 2000.

The NCCSAP assisted developing countries to raise awareness of the problem of climate change, and increase the involvement of policy makers, scientists and "broad layers" of the population in the debate on climate change. In 2000 an external evaluation stated that a continuous effort was needed to institutionalize solutions to the climate change problems in developing countries. The key thematic lesson from the first phase of the NCCSAP is that vulnerability and adaptation analysis cannot be driven solely by climate change modelling. Livelihood vulnerability must be given at least as much emphasis as biophysical vulnerability, not least because they are interdependent. The evaluation further recommended a stronger effort to make studies policy relevant.

On the basis of the evaluation the Dutch government invited expressions of interest for organizations to bid for a second phase under a tender procedure. Afterwards the tender procedure NCCSAP was contracted to the ETC Foundation. The second phase began in March 2003 with 14 partner countries: Bangladesh, Bhutan, Bolivia, Colombia, Ghana, Guatemala, Suriname, Mali, Mongolia, Mozambique, Tanzania, Vietnam and Yemen. The second phase of the program shifted focus and centred it on vulnerability, impacts and adaptation (with no support for climate mitigation). Analysis was derived mainly from bottom up investigation of local livelihood practices in the face of climate variability and change (rather than top down investigation of the impacts of climate change on economic sectors); and written material was produced directly in support of relevant policy dialogues rather than solely for publication to the scientific community.

To emphasize that the new phase of the program was more than a research exercise, the ETC dropped the word "studies" from the program's name and the initiative became known as the Netherlands Climate Assistance Program (NCAP).

This shift in emphasis from NCCSAP to NCAP reflected the developments in the international climate negotiations under the UNFCCC, which placed increasing emphasis on the linkages between climate change and poverty alleviation, and the need to move beyond impact studies towards action.

> **In general, climate change and poverty are intrinsically linked and attacking one can lead to synergistic effects.**
> *Bangladesh team*

The program's start-up period involved setting up an international technical assistance team and a large number of identification and start-up visits to partner countries. After a great deal of discussion and negotiation, proposals were received from most of the fourteen countries in the program. At this point the program's technical team began to assist in the (further) elaboration, and implementation of activity plans and technical training workshops were organized for country partners.

As project work progressed in participating countries, additional clarity was needed on progress indicators for the program as a whole. In consultation with the DGIS, the NCAP had adopted a set of progress indicators. The indicators included issues such as project management, study quality, effective coordination with other relevant initiatives, feedback from stakeholders, raised awareness of policy-makers in ministries, and opportunities for international cooperation.

These indicators were considered a little too vague and unspecific, and greater clarity was sought on the overall strategic goal of the NCAP. So the NCAP Advisory Committee and technical assistance team were consulted. The conclusion was reached that elaborating the indicators midway in the program would not be without negative consequences. Comments on the indicators reflected differences of opinion on the overall strategic direction of the program, which were being played out in the wider discussion on support for climate adaptation at that time (crudely: from mainly providing support to the UNFCCC reporting requirements on the one hand, to mainly assisting countries to build operational experience with adaptation projects on the other).

> **While managers may have a good idea of the overall project objectives, creative and innovative solutions may be provided by project stakeholders, ideas which could even change the implementation direction or intended outputs. In such a case, the purpose and overall objectives of the project can remain but a reorientation of certain specific objective or outputs may be useful to better fit the practical reality.**
> *Vietnam Team*

Indicator revision would likely have caused confusion for country project teams (because most country teams were in the middle of implementing projects that include these indicators in their workplans). So a pragmatic approach was taken to apply the NCAP indicators flexibly, and to provide technical assistance tailored to individual country circumstances, rather than within a "one size fits all" methodological framework. The indicators were still kept as guidance, but they were applied in a pragmatic manner taking the needs of individual countries into account. This approach was later praised by the external evaluators as one of the factors that contributed to the success of the program.

Around 2007, the NCAP faced many in-built challenges and difficulties that tended to hamper progress: electronic communication of complex issues over large distances is often not effective; differences in language and culture can be a barrier to quick and effective communication; partners in developing countries often have a hectic workload and can become distracted by the various demands on their time; project teams tend to lack knowledge of climate vulnerability and adaptation issues and often lack the know-how to utilize analytical methods and tools; and inter-agency rivalries in partner countries can impede project implementation. Also, in this period before the political effects of the Al Gore movie, An Inconvenient Truth were being felt in developing countries, the launch of the British Government's Stern Review on the Economics of Climate Change and the publication of the Fourth Assessment Report of the IPCC (which stated that 'climate change is 99% certain'), there was still insufficient political support for adaptation to climate change among key decision makers.

Despite the above challenges, the NCAP partners were making progress. There was effective collaboration with the technical assistance team. Innovative, policy relevant, climate adaptation study projects had been institutionalized, and awareness had begun to be raised in-country beyond the usual circle of climate change experts. Moreover, a growing body of good quality written products was being generated by country teams as demonstrated by the country synthesis chapters contained within this book. To make the NCAP outputs more widely accessible, the program website design was updated and written products were made available to download.

Also, in 2007, a Memorandum of Understanding was drawn up between the NCAP and the United National Institute for Training and Research (UNITAR) program: the Advancing Capacity to Support Climate Change Adaptation Program (ACCCA, see www.acccaproject.org).

Both the NCAP and the ACCCA were working in many of the same countries with the same country partners (using the same external technical assistants). In substance, both programs were working in the same thematic areas facing a similar challenge: moving from a previous phase that concentrated on biophysical vulnerability assessments to a current phase that attempts to move through livelihood vulnerability studies to setting priorities for adaptation. This presented a strong argument for a level of information sharing and cooperation between the two programs. Specifically, a decision was taken to cooperate on three projects in Mali, Bangladesh and Ghana and to underpin this with a financial transfer from the NCAP to the ACCCA.

Furthermore, work began to investigate climate adaptation targets. This work used the various risk and vulnerability assessment methods and various indicators of adaptive capacity used in the disaster risk reduction community that may be partially applicable to national level mainstreaming of climate change adaptation as a basis. So a partial methodological basis seems already to exist. The challenge was whether it would be feasible to take this methodological basis and to overlay impacts to climate change and sensitivity to these impacts in a way that would be both scientifically robust and translatable into policy goals for adaptation.

In order to explore this further, a meeting was held with NCAP partners from Bangladesh, Bolivia and Mongolia, members of the NCAP technical assistance team and a representative of the Asian Disaster Preparedness Centre. During the two days the group drafted a preliminary set of procedures that would be needed to specify adaptation policy targets. In addition arrangements were made for this adaptation mainstreaming approach to be explored further in the three countries represented. The results of this investigation are detailed in the conclusions section of this book.

All of the project activities contributed to mobilization of local resources, including information and data, technical, financial and human resources, especially the collaboration from other activities and projects for the common target: to formulate the climate change policy for the country and the province.
Vietnam Team

To identify critical issues, challenges and future priorities in the context of strategic planning for climate adaptation, ETC organised an international partner meeting in May 2008. The meeting was held in the Netherlands and was conducted as a collaborative exercise in which the NCAP partners shared experiences and learned lessons with Dutch NGOs.

Group discussions touched on: the importance of promoting access to water; the need for awareness raising among rural communities; the imperative of human and institutional capacity building; the importance of starting with local indigenous knowledge in efforts to improve access to appropriate technologies; and the importance of an understanding of the social context in respect of this. This resulted in a set of recommendations, which are described in more detail in the conclusions section.

Partners felt that the challenges being faced are both technical (including understanding how best to plan to adapt, the costs of climate resilience, and improving climate information) and political (including the separation between environment and development processes and improving the awareness of developing country governments of climate risks). A general consensus among the partners was the need to move ahead with the NCAP.

Progress during the final months of the NCAP continued steadily. The effective working relationships throughout the program resulted in good quality outputs from almost all countries, produced with the support of the international technical assistance team. Furthermore, the NCAP's collaboration with the UNITAR's Climate Change Program (CCP), under its Advancing Capacity to Support Climate Change Adaptation (ACCCA) program also came to an end with progress reports signifying progress achieved in the three countries involved: Mali, Ghana and Bangladesh.

The NCAP project has analyzed the policy regime and institutional framework; instead of proposing a separate climate change policy. Similarly, 'sectoral integration' has been identified as the way forward, instead of development of a Climate Change Action plan to be implemented by one designated government agency. This approach has been adopted in the BCCSAP, placed before the donor community by Bangladesh at an international meeting in September 2008, in London.
Bangladesh Team

In addition, the investigation carried out under the NCAP into the applicability of adaptation targets was rounded off with the conclusion that defining targets for adaptation can help to focus adaptation efforts on priority sectors/areas, and can also assist in measuring the effectiveness of adaptation actions (progress in responding to the adverse impacts of climate change). However, target focus has to be complemented with a process focus that measures adaptation capacity in a changing environment accounting for social learning, uncertainty, and varying adaptation landscapes. The country pilot projects carried out under the NCAP supported this argument by showing how the process of setting targets allows identification of priority sectors, regions and locations and provides ways of measuring the effectiveness of actions related to building adaptive capacity and adaptation.

Lastly, all contracts were closed and written products made available via the program's website www.nlcap.net. Furthermore, country reports and lessons learned are summarized on www.weADAPT.org (See also www.wikiADAPT.org), where one can access the main findings, methodologies and lessons learned from each NCAP study, as well as the general lessons learned from implementing the NCAP. Finally, for a quick and easy snapshot of the NCAP see the Google interface of weADAPT, which allows for the visualization of the different NCAP projects using a Google Earth working space.

Adapting to Climate Variability and Change in Bangladesh

A. Nishat, S.G. Hussein, M.A. Matin, A.R. Mollah, I.Tellam

Introduction

Background

The coastline of Bangladesh is particularly vulnerable to the sea level rise in the Bay of Bengal on account of the low-lying deltaic environment. The tropical cyclones, which strike the coastal areas periodically, create misery and loss of life, property and damage to the ecosystems. The total area of the coastal belt is about 39,300km^2 (27% of the country's total area) and more than 29 million people (22% of the national population) live in this fragile and vulnerable area. Climate change may influence erosion, accretion, floods, waterlogging, cyclones and tidal surges in the coastal region. Against this backdrop, the people who live in the coastal areas are dependent on its resources for their livelihood sustenance and already belong to a vulnerable category. The livelihood of the people has been affected through the impacts of climate change on agriculture, fisheries, livestock, shrimp farming, off-farm activities and even the locations of human settlements. These situations have led the people to devise unique coping strategies for their survival. The future of their livelihood and for that matter, the human settlements in this region will depend on viable adaptation measures to cope with the future extent and consequences of global warming.

Approach and Methodology

The activities of the Netherlands Climate Change Assistance Program (NCAP) have been designed in order to explain the three common questions: what are the demands of stakeholders? What is available to them? And how can their needs can be communicated to policy makers to steer necessary action?

A combination of the participatory approach and scientific tools and data was adopted in this project, to attain maximum input and ensure the interaction of stakeholders. Sustainable livelihood framework was used extensively to understand the local vulnerability issues. These approaches were based on the premise that there was a need to acquire an in-depth understanding of the local issues in terms of people's perception and understanding of climate change and institutional capacities to respond to the perceived changes.

Description of the Study Area

Noakhali is one of the coastal districts of the country. The district has an area of 3600.99km^2 and is bordered by Comilla district to the north, the Meghna estuary and the Bay of Bengal to the south, Feni and Chittagong districts to the east and Lakshmipur and Bhola district to the west (see figure 1). The absolute location of the district is 2200˚ N to 23010˚ N latitude and 89050˚ E to 91030˚ E longitude.

Noakhali district consists of six *upazilas* (sub-districts) namely Noakhali Sadar, Begumganj, Sonaimuri, Chatkhil, Senbagh, Companiganj and Hatiya. The study area, Noakali Sadar *upazila* is located between 22038° and 22059° N and 90054° and 91015° E. The *upazila* occupies an area of 1071.66km^2, including 220.34km^2 of rivers and 103.71 km^2 of forested land. The *upazila* is bordered to the north by Begumgonj and Senbag *upazilas*, to the east by Compnaiganj, to the southeast by Hatiya *upazila* of Noakhali district and to the west by Ramgati and Laksmipur *upazila* of Laksmipur district. The southwestern part of the *upazila* faces the sea and forms part of the Meghna estuary. Noakhali Sadar *upazila* is now split into two *upazilas*, namely Noakhali Sadar (or Sudharam) *upazila* and Subarna Char *upazila*.

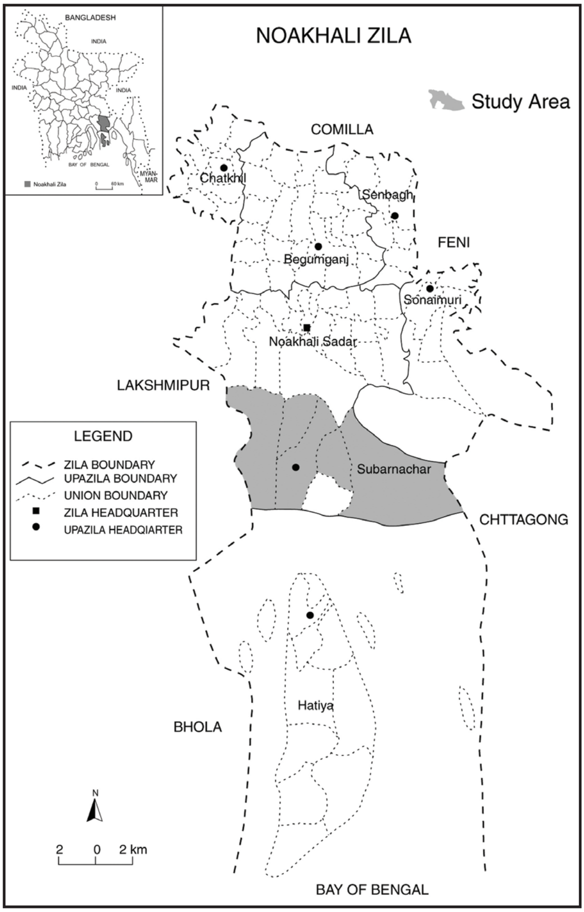

Figure 1: Location of the Study Area

Physiographic condition

The area represents an extensive flat, coastal and deltaic land, located on the tidal floodplain of the Meghna River delta, characterized by flat land and low relief.

The area is influenced by diurnal tidal cycles and the tidal fluctuations vary depending on seasons, being pronounced during the monsoon season.

The population of Noakhali Sadar and Subarna Char *upazila* in 2001 was 766,722 with the male and female population divided almost equally. The population growth rate is 1.65% and density is 715km^2. Urban population is 14.52%. Literacy rate for males is 51.43% and for females is 45.04%.

Natural Hazards

Noakhali, being exposed to the Bay of Bengal is prone to multiple hazards. Cyclones are frequently occurring disasters, which hit the coastal villages every year. Sometimes, cyclones accompanied by tidal surge inundate the very remote coastal areas of the district and cause massive destruction. Along with these, annual flooding due to excessive rainfall and poor drainage systems has recently been devastating. Waterlogging is common in and around the Sadar area. Rapid population growth and intensification of human activities are the main contributors to an increase in risk, especially in the remote areas adjacent to the sea. Very recently, there has been an additional (Tsunami hazard) hazard which is also threatening the vulnerable coastal populations.

Vulnerability

Research on the vulnerabilities of coastal inhabitants indicates that the vulnerability of the people of Noakhali is exacerbated by the natural disasters and their socio-economic status. The challenges posed by waterlogging, floods, lack of employment opportunities, ownership of *khas* land, cyclones, low prices of cultivated crops etc. increase the vulnerability of the small and landless farmers. In the case of the fishermen, cyclones, depletion of fisheries resources, dearth of capital or seed money, deteriorating law and order situation, weak communication facilities etc. make them extremely vulnerable. Laborers also fall prey to the vulnerabilities arising out of the lack of employment opportunities in both urban and rural areas, cyclones, ownership and claims over *khas* land, lack of safe drinking water and poor communication networks.

Life and Livelihood

Climate change may affect the coastal region through salinity, erosion, accretion, floods, waterlogging, cyclones or tidal surges. Considering this, the people living in the coastal area and depending on its resources for their livelihoods belong to a vulnerable category. Livelihoods of people have been affected through the impacts of climate change on agriculture, fisheries, livestock, shrimp farming, off-farm activities and even the locations of human settlements. Over the centuries, climate variability and extreme weather events have caused deaths and destruction of assets, resources and livelihood practices, which eventually have led people to devise indigenous coping strategies for survival. The practiced coping mechanisms within the communities and their traditional knowledge-base enable them to organize at the community level and manage disasters. Even their wealth of knowledge regarding the management of their livelihoods in different changed climatic scenarios is substantial.

Perceived Changes in the Observed Climate

The changing scenarios of climatic events that have been perceived and mentioned by the participants of focus group discussions (FGDs) carried out at the study area are as follows:

- *Excessive rainfall in a few successive days:* Torrential/huge rainfall within a short period (in days) is becoming more common, rather than constant rainfall over a wider span of days as in the past.
- *Change in the rainfall calendar:* Time/season of rainfall has changed over the years, what the participants termed as ‘untimely rainfall’ that poses much difficulty in the cultivation of crops. The highest annual rainfall still occurs in the months of Ashar and Srabon. However the past 5 or 6 years’ rainfall in Ashwin and Kartik has been increasing significantly causing severe devastation to *Aman* crops and to culture fisheries.
- *Increase in Temperature:* Temperature, as perceived by the participants in general, has increased recently compared to the past.

- *Routine occurrence of drought:* Drought is being experienced every year in a routine manner. Both the time-span and intensity of drought have increased over the years. Excessive heat is felt during drought-time.
- *Colder winter:* The span of winter has become shorter but the intensity seems to be higher.
- *Excessive fog during winter:* Fog/mist being experienced is erratic as far as timing of occurrence is concerned but the intensity and volume are higher/greater than the past.
- *Salinity in soil:* According to the participants, salinity is noticeably present in the soil of the whole area covering both Subarna Char and Noakhali Shadar but not up to that extent in water. Due to this salinity in soil, bricks made of soil remain saline affected and this causes brick-made house to be less durable. But to their relief, the extent of salinity has declined these days after the construction of embankments.
- *Salinity in drinking water:* Although salinity in surface water has remarkably declined, it continues to affect drinking water extracted from shallow tubewells.
- *Waterlogging:* Waterlogging has become a major climatic concern for all the inhabitants of the area. In the past, lands used to become temporarily waterlogged due to inundation fueled by an unusually high-tide. After the construction of *veri-bandh*[1] in 1974 (in some areas, i.e. in Charclerk, an embankment was constructed about 4 or 5 years ago), sea water no longer enters the area, but following excessive rainfall during the rainy season water remains stagnant and turns the whole area into a 'seasonally waterlogged' area (for at least 5 to 6 months) causing great misery to the people. The extent of waterlogging, according to them, is increasing day by day.
- *Occurrence of tidal surge:* Tidal surge no longer affects the people of the area inside the embankments. Although in the past water used to enter and inundate the area with unusualy high-tides in the time of full-moon. During those days there was no well-built, designated cyclone shelter in the coastal areas. Modern multipurpose cyclone shelters were built after 1991. Tidal surge now no longer occurs due to the existence of embankments. However, it still torments the life of people residing outside the embankments, especially when cyclone-led surge routinely occurs once or twice every year.
- *Occurrence of flood:* Inundation is very common, caused mainly by excessive rainfall during the rainy season. But this type of inundation can not be termed as a 'flood' defined in the usual way which is caused by the overflow of water from rivers. The construction of embankments is obstructing the inflow of water from the overflow of the river Meghna as used to be seen in the form of flooding in the past. Flood still occurs these days but it is not as severe and as frequent as it had been in the past due to structural changes.
- *Frequency of occurrence of cyclones:* According to the participants, the frequency of cyclone has lessened over the years. In the past, cyclones coupled with tidal surges used to devastate the whole area.

Problems Due to Climate Change

Participants were asked in all the discussions to outline the problems and sufferings, personal, social and economic, that they confront in their day-to-day lives afflicted by the occurrence and variability of the major climatic events.

Waterlogging

- Low-lying houses usually go under water or are, at least, greatly damaged by water.
- Severe damage takes place in the case of crop-agriculture, especially when it is inundated.
- The very process of cultivation is hampered, in particular timely cultivation.
- Both the *Aus* and *Aman* crops are potentially at high risk of being damaged due to waterlogging, especially when the lands start to be inundated at the time of harvesting of *Aus* crops causing immediate damage to that crop as well as stalling the process of sowing for *Aman* crops.
- The untimely excessive rainfall in Ashwin and Kartik causes devastation to *Aman* paddy; just before harvesting this rainfall creates the problem of waterlogging which leads to a huge loss in *Aman* production.
- Waterlogging causes severe damage to vegetable cultivation.

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1 Embankment to protect the area from tidal surge.

- Even if serious loss does not occur in the case of crop-cultivation in the waterlogged areas, the yield declines mainly due to the damage to saplings.
- Saplings in waterlogged areas become infected with pests/insects. It is impossible to use pesticides or insecticides as they are merely washed away.
- The cultivation of potatoes, peppers, soybeans, nuts, etc. is not possible during the period of waterlogging.
- Trees are severely affected by any prolonged standing of water. Jackfruit trees, neem trees, papaya trees, etc. die, in their thousands, because of waterlogging.
- Waterlogging causes enormous losses to fisheries in the area, especially when it becomes impossible to keep the fishes inside the ponds/water reservoirs with the rise of water level that causes an overflow of water. The extreme rainfall in October 2004 caused almost total devastation to culture fisheries as the banks of the ponds overflowed and the fishermen were not prepared.
- Houses, especially low-cost houses made of mud and bamboo become dilapidated due to stagnant water and eventually collapse.
- During prolonged periods of waterlogging, a number of people die from snake-bites. Loss of domestic livestock such as cattle, chickens, ducks, etc. also occurs from snake bites.
- Since it becomes difficult for people to go outside during these periods, people incur huge losses from unemployment and lack of income/earnings.
- Communication becomes disrupted since most of the roads and paths are damaged causing difficulties for people, especially the elderly, young and disabled. Access to health facilities becomes a great worry for families.
- People now use shallow tubewells for drinking water; whereas previously they used to drink surface water, pond-water in particular. There are threats involved in using this water however, as there is often a threat of arsenic contamination.
- During the period of waterlogging, the problem of sanitation becomes acute. Cases of diarrhea and other waterborne diseases increase.
- People face energy insecurity during periods of waterlogging.
- Waterlogging ultimately leads to a situation of environmental degradation. The polluted standing water causes severe environmental hazards.
- It can be summed up that waterlogging increases people's vulnerability; especially poor people who havea lower shock absorbing capacity.

Drought

- During the winter/dry seasons the southern part of Noakhali Sadar and most parts of Subarno Char face the problem of salinity. This leads to a substantial part of these lands remaining abandoned during this dry winter season.
- A substantial part of Noakhali Sadar and Subarno Char does not have an electricity supply and therefore cannot have deep tubewell irrigation. These people cannot use *Boro* cultivation methods which need intense irrigation. Besides this problem, the salinity increase during the dry season does not allow people to cultivate their crops.
- The problem of drinking water becomes evident in drought conditions. In many areas tubewells are of no help as the water level is drastically lowered.
- Fishermen who own culture fisheries face tremendous problems. The ponds become dry and for most fishermen, droughts lead to a lack of work.
- As a result, fishermen face unemployment and food insecurity during dry winters.
- People try to grow vegetables in the winter, which is greatly hampered by severe drought conditions.
- There are outbreaks of various diseases.

Cyclones

- Cyclones not only cause loss of human lives but loss of livestock such as cattle etc.
- The physical effect of cyclones is evident. They destroy houses, especially weakly-built ones.
- People face loss of physical assets (houses, gardens, household utilities, boats, tubewells, latrines, poultry, cattle, roads, embankment etc.).

Salinity

- Salinity severely affects the potential to cultivate *Boro* crops. Prevalence of salinity in drought conditions limits farmers' options for cultivation, which causes income loss and insecurity.

Changes in Temperature

- Due to heat stress during hot summers, people, especially those working as farmers and day laborers, face serious physical stress that tends to affect their capacity to work.
- The day laborers cannot work at a stretch due to scorching heat in summer and in the month of Bhadro, which causes income loss and insecurity.
- It is very difficult for the fishermen to catch fish at any point other than during the day in winter due to the extreme cold.
- It is usually women and children who are responsible for fetching water from distant tube-wells. It is more difficult to do this in the extreme heat of the summer.

Coping Measures: Inherent Resilience

Coping practices are often spontaneous and an immediate response of vulnerable people to different shocks. People use the means that are available to them in order to cope. The livelihood conditions of the people largely depend on the ownership of or access to capital by households which broadly determines their capacity, scope and survival strategy. The asset base is categorized by human, social, natural, physical and financial assets.

Table 1: Typology of Assets which are used for Coping

Group	Assets
Human	Household members, health, education, training
Social	NGO/cooperative groups, network/connection
Natural	Land, water, homestead, wetland, pond
Physical	House, tube well, latrine, electricity, cattle, poultry, tools and utilities, boat, net
Financial	Savings, credit, food/cash assistance (safety nets)

Coping Starts with Strengthening Houses

At the very outset of the study the team made a reconnaissance visit to selected areas. Other than the *Pouroshova*[2], in most of the unions *kacha* houses are made of bamboo (*muli* bamboo) and tin roofs are very common; jute sticks are used as walls and jute fabrics as ceilings. People who are very poor use mud as a house building material. These types of houses are more vulnerable to natural disasters than the brick-built houses of comparatively wealthier families.

Everyone tries to strengthen their houses before the seasons of rainfall and cyclones start. They do this in a manner which is within their means. Usually the foundations of all the houses of Noakhali Sadar and Subarno Char *upazila* are raised so that the rain water cannot enter the house. Usually they raise the platform to a height which will protect the houses from regular/average flooding from rain water. The families who have some extra money to invest in their houses, raise the platform of their houses above the average height of anticipated rainfall which causes devastating waterlogging conditions. The kitchens are also placed on raised platforms.

2 An urban centre, where an elected body takes care of local level development and management issues.

When the living conditions deteriorate due to excessive rainfall, people move all their household utilities on to a bed where all the family members not only live but also cook. The internal structure of a house has a space in a false ceiling called a *darma*. These ceiling-like raised/high platforms are built inside the houses to keep ownership documents/deeds of lands, other important papers/documents, dry food, rice, pulses, salt, sugar (*gur*), matches, candles, kerosene, quilts, kantha etc. safe and stored in the case of an emergency during the waterlogged period. A staircase made of bamboo usually connects people to the *darma*.

Ovens are made using mud, tin, and cement and kept on *darma* in order to use during waterlogged periods/times of flooding. Cooking is done on top of beds using those ovens, which the participants have learned to use via demonstrations/publically performed mass communication campaigns. Raised platforms for urination and defecation purposes are also constructed from bamboo.

Houses outside the embankments are usually raised on even higher platforms, allowing the regular tidal surges to flow without any interruption. This platform is about 4 to 5ft high. Then on this raised platform people again raise another platform, about 1 to 2ft high, building the house on this secondary raised platform. This secondary raised platform helps to protect the house from abnormal tidal surges. People do post-harvesting activities on the primary raised platform. Other than this two-stage raised platform, the internal arrangements of the houses outside the embankments are almost the same as the houses inside. The financial conditions of the households outside the embankments are the worst. Most of the houses here are built of mud. There are latrines in some houses, but the overall sanitation conditions are not at all satisfactory.

People carry out preparations before the cyclone season starts. Preparations depend on their capacity to invest. Usually they tie the corners of their house with strong ropes or wires to the ground. To protect from rain they repair the ceiling almost every year. Walls made of mud and ceilings made of jute sticks or leaves are especially taken care of before the rain comes or cyclones strike. People who are very poor and do not have the means to repair their houses with minimal effort, take shelter in a neighbor's house, adjacent school or *madrasa*. During the waterlogging, livestock shelters in the same room as the family lives. Very few families can afford the luxury of keeping a separate shed for cattle which is locally called a *Goal Ghar*.

Coping Strategies for Agriculture

As agriculture is the main sector of economy in Noakhali Sadar and Subarno Char *upazila*, a detail edeffort has been initiated to study the corrolation of changes in cropping patterns with different climatic events. Different cropping patterns are followed in different unions of the same *upazila*. The pattern depends on land type, salinity, land quality, availability of irrigation facilities etc. The practiced cropping behaviors of the selected sample sites of Nokhali Sadar and Subarno Char *upazila* are summarized later. Details of agricultural coping practices are also described later.

Coping Strategies Taken by the Fishing Community

For the past 15 to 20 years culture fisheries have been kept by the inhabitants of Noakhali Sadar *upazila*. In some areas of Subarno Char, which are in the southern part of the *upazila* and close to the Meghna River, some people prefer to catch fish in open water.

Employment Pattern of Fishermen

- Culture fish in ponds and sell them to local markets;
- Catch fish in open water/rivers/*khals* and sell them to local retail/wholesale markets;
- Trade in fish – do not culture or catch fish themselves but buy fish from local wholesale markets and sell to local retail markets;
- Trade in fish along with other small-scale businesses in local markets.

Problems Encountered by the Fishermen

The fishermen reported through a consensus that:

- The availability of fish has declined significantly;
- Not only has the availability gone down, but the number of species of fish in open water has dramatically decreased. About 75% of the species previously available are not seen or caught anymore.
- To catch fish, fishermen now have to go to deeper water.

It is understandable that the problems of culture fisheries and the fishermen who fish on open water are not the same. The fishermen who only depend on fishing and do not have any other trade or business also have unique problems. Fish traders have business throughout the year, but fishermen in culture fisheries face employment insecurity in dry seasons, especially in the months of Falgun and Chaitro due to the drying up of the ponds. They then employ "crisis coping" strategies which will be discussed later on. Fishermen who fish in the rivers/sea must have equipment to pre-warn them of cyclones. They have radios in their trawlers and head into shore following the alarm signal. However, they are not alerted before the danger signal reaches 8, they have reported.

Ownership pattern

- Fisherman owns his own pond, cultures fish by himself, collects fish from the pond with his own net and own effort, sells in the local market by himself;
- The owner of the pond is not directly involved in the culture fishery. Rather the owner hires somebody to run the ponds and catch the fish. Sometimes the net can be owner's and sometimes the net can be hired labor's. The hired labor can earn Tk.100-125 in the peak seasons.
- Sometimes fishermen arrange leased ponds and culture fish there. They have to pay a certain amount for the lease to the pond owner; this payment is made usually on an annual basis.
- Usually the fishermen who catch fish in open water have their own/collective nets. These collective nets are owned by the fishermen who fish together in the same trawle; often they themselves make the nets. They do not have trawlers of their own. They go to sea for at least 15 days at a stretch. They store food in their trawlers for these days. The cost of their food is partly borne by the trawler owners. The rest of the cost of fishing apart from the fuel for the trawler must be borne by the fishermen. They have to pay half of their earnings to the trawler owner. These fishermen suffer from serious insecurities due to dangers such as pirates.

For the fishermen involved in culture fisheries, excessive rainfall and waterlogging cause severe devastation to their livelihoods. During the waterlogging in October 2004, every fisherman suffered serious losses as their fish spilled over the banks of the ponds. Consequently they have raised the banks of their ponds to a height which can cope with a regular waterlogged conditions as well as an extreme height of water. Another coping method is to net the whole surface of the pond to prevent the fish from escaping. People who can afford this netting can try this coping strategy. However, fishermen, who are very poor and cannot afford these methods, have to accept the reality that they do not have any control over the situation. They seek alternative livelihoods like day labor, rickshaw pulling, small trade etc.

Coping with Food Insecurity

As mentioned earlier, people face seasonal food insecurity. Food 'security', means the availability of food three times a day. Here, the question of food quality is not relevant. Focus group members agree on the changes in their food intake both in terms of quantity and quality. As shown in figures 2 a) and 2 b), their protein intake has drastically decreased in recent years, although it shows improvement for the families of fishermen, who can regularly eat fish. Pulses have always been a major source of protein for poor people. The preferred variety was mung, however people could easily afford mosuri. Now mosuri is too expensive for the majority of people. They now eat cow-peas (buter dal) which used to be used as cow fodder. This fall in protein intake causes serious nutritional problems, especially in children and pregnant women. In the months of food insecurity, mentioned earlier, the families often exist in famine-like conditions (locally known as monga). During monga they do not have their usual three meals a day. For fishing households, the dry season of Falgun-Chaitro brings food insecurity, Ashwin-Kartik for farmers, and Ashar-Srabon for day laborers. Often they cope with extreme food insecurity by consuming smaller amounts of food, and most often by forfeiting one or two meals a day. In addition, they avoid unnecessary movement, thereby conserving energy and pass most of their time sleeping. Carbohydrates form the major part of their food intake during these times of food insecurity.

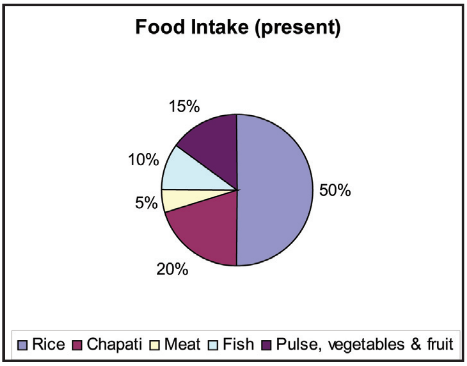

Figure 2 a): Present Food Intake

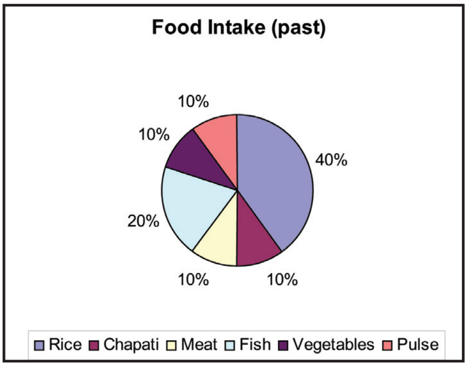

Figure 2 b): Past Food Intake

Women were specifically asked how they manage this lack of food security. Often women collect vegetables from common property resources (*tokano*). In most cases food priority is given to the male member of the household. Then the remaining food is distributed among the old and children. Women come last. If something is left over they can have that.

To face natural disasters women often store dried food within polythene packs and store it on *darma* in their house as a coping mechanism.

Availability of Safe Drinking Water

Both in Noakhali Sadar and Subarno Char, people take water from tubewells for drinking. They are aware of the problem of arsenic. Not every household possesses a tubewell. Those who do not have a tubewell in their house have to go to a neighbor's house, school or *madrasa* to fetch drinking water. Usually the women or children in the family are responsible for this job.

When there is excessive rainfall and waterlogged conditions, sometimes polluted water reaches the water level of tubewells, and then it is extremely difficult to obtain safe drinking water. During waterlogging or flooding, water is purified either by boiling or by using alum (*fitkari*). However, as electricity is not readily available during flooding it is difficult to boil water for drinking. Rainwater is collected to use as drinking water when all the tubewells become flooded. On top of this, wood is stored on *darma* to be used as firewood for boiling pondwater.

The inhabitants of the Subarno Char in particular, had previously been used to drinking water from shallow tubewells. But now-a-days, with the dissemination of knowledge, they usually drink water from deep tubewells since the chance of water being contaminated is much lower. In the past, when they did not have any specific knowledge of contamination, they used to drink surface water as well.

Coping with Energy Insecurity

As shown in figures 3a) and 3b), biomass is still the most important source of energy. But as the common property resources decrease over time and agriculture tends to depend on technology rather than animal power, the availability of cow dung has decreased. In farmers' families agricultural residues are an important source of energy, while the families of fishermen are largely dependent on fuels bought from the markets. Dried-up maize plants, paddy straw, roots and branches/ creepers (*lata*) of bean plants etc. are used as firewood for cooking. During waterlogged periods this fuel is stored on *darma*.

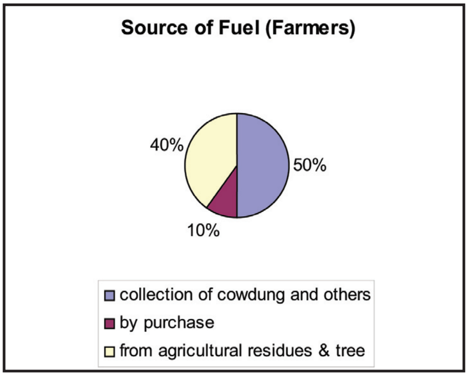

Figure 3 a): Source of Fuel (Farmers)

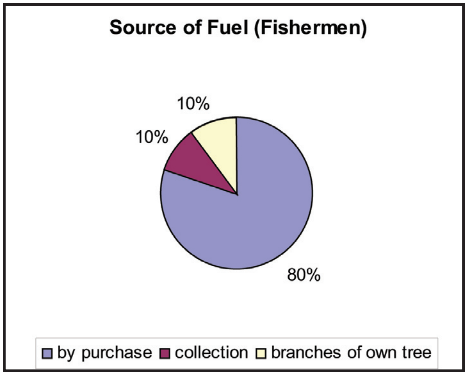

Figure 3 b): Source of Fuel (Fishermen)

Coping with Crisis

Households adopt a wide range of strategies to cope with crisis. Sometimes, immediately after or during the crisis, people take out loans from local *Mahajans* (wealthy people) with high interest rates (usually 100 tk. interest per month for 1000 tk. of loan) to deal with their emergency needs. If, during or just after waterlogging or drought, diarrhea and other diseases breakout they often resort to informal loans. Often in this situation they sell their assets. Of course, selling land is the last resort for them.

Seasonal migration is very common, especially during the dry season when farmers cannot cultivate land due to salinity or lack of irrigation facilities. People often leave their houses and go to nearby cities in search of job opportunities.

Hazard Specific Coping Strategies:

Waterlogging

- To cope with waterlogging, some houses are being built with fences made of bamboo (*muli* bamboo) and wood. Yet most of the houses are made of mud and bamboo fences.
- The foundation floors of the houses are raised so that water does not enter, until it reaches a certain level.
- In the case of crop-agriculture, late varieties of *Aman* rice such as kazal-shail, raje-shail (both black and golden), chapraish, kartik-shail, dholamota, leiccha, nazir-shail are sown as they are more resilient to waterlogging.
- During the waterlogged period cattle are kept on raisied floors. Seedbeds are also prepared by raising the land with soil/mud. In some places crop-land is raised quite considerably for cultivating winter crops (*rabi* crops).
- As a precautionary and safety measure, the sides of the fish ponds are raised up to a certain level so that the fish are not washed out of the ponds.

- Fishermen catch fish in ponds, reservoirs and sometimes in waterlogged land since almost all the canals are filled up with silt and the Meghna River changes its course due to flooding.
- Ceiling-like raised/high platforms (*darma*) are built inside the house to keep important documents, dry food such as cheera, muri, rice, pulses, salt, sugar (*gur*), matches, candles, kerosene, quilts and kantha, etc. safe and stored during the waterlogged period.
- Those who live from hand to mouth become compelled to borrow money. If they fail to borrow any money or food, they have to go hungry.
- Rainwater is collected to use as drinking water since tubewells are unusable during the waterlogged period. As well as this, wood/branches of trees are stored on *darma* to be used as firewood for boiling pondwater.
- During waterlogging/flooding, water is purified either by boiling or by using alum (*fitkari*).
- Dried-up maize, paddy straw, roots, branches and creepers (*lata*) of bean (*seem*) plants, are used as firewood for cooking.
- Cow-dung collected either from own cattle or from other sources is another source of energy for cooking.
- Ovens are made using mud, tin, and cement and kept on *darma* for use during waterlogging/flooding. Cooking is done on top of beds using those ovens, which the participants have learned to use through demonstrations performed in mass communication campaigns.
- Raised platforms are made of bamboo in order to use for urination and defecation purposes during waterlogging/flooding.

Salinity

- The inhabitants of the Subarna Char Thana in particular previously used drinking water from shallow tubewells. But now-a-days, with the dissemination of knowledge, they usually drink water from deep tubewells since the chance of water being saline is much lower. In the past, when they did not have any specific knowledge about salinity they used to drink water from ponds as well.
- Now even when people drink water from shallow tubewells, they do purify it using alum (*fitkari*).
- An effect of salinity is that the complexion of people's skin becomes darker. But people adjusted to this phenomenon over time.
- Farmers use fertilizers such as gypsum, potash, etc. to reduce salinity of the land.
- The extent of salinity is different for different sections of uneven land. Therefore, to make the extent of salinity equal the farmers first make the land even and then use the various types of fertilizers mentioned above.

Drought

- With the onset of drought, land becomes covered with a thin layer of salt. Farmers thoroughly plough their land in order to reduce concentrated salinity.
- Since water becomes scarce and less available farmers bring water from ponds to use on their land for cultivation.
- Farmers usually use pitchers for fetching water from nearby ponds. Relatively well-off farmers use shallow tubewells and machines to channel water from ponds.
- Throughout the drought period there is a shortage of drinking water availability since water cannot be withdrawn from shallow tubewells. People have to look for deep tubewells nearby.

Cyclones

- In a bid to reduce the extent of loss of lives and resources, The Red Crescent Society alert people against danger and motivate them to adopt safety measures with the warning of cyclones.
- Upon hearing these announcements by the government through the radio, people take refuge in cyclone shelters.
- In addition to cyclone shelters, people take shelter in strongly built houses.
- After 1991, another practice of taking shelter during cyclones has emerged with people and their cattle taking refuge on higher ground.
- People usually secure their houses so that they can withstand the severity of the storms.
- They keep food in mud pots and bury them in the ground.
- People keep seeds in polythene bags and bury these in the ground too.

Floods

Due to the erection of the embankments, no drastic flooding has occurred since 1970. After the building of the embankments the only flooding has been in the form of severe waterlogging. Therefore, peoples' coping practices for flooding are similar to those for waterlogging and cyclones.

Women's Vulnerability to Natural Disasters in Noakhali

In Noakhali, society supports a rigid gender division of labor that perceives men and women's roles differently and distinctly defines women's mobility, duties and responsibilities. The traditional family model and gender roles in Noakhali are changing very slowly. However, due to extreme poverty and the increased inability of families to provide protection for their women, there is an increased mobility of rural women in economic activities when previously women would have stayed at home. Other than the *Pourashava* areas and some urban areas, the gender roles imposed by society are usually considered 'natural'.

Gender Division of Labor:

In Noakhali, women's positions are rooted in their social traits, patriarchy and gender division of labor. Men's activities are considered as income generating, while women's activities are mostly limited to the domestic domain. The table depicts the gender division of labor in Noakhali as revealed during focus group discussions with both men and women.

Table 2: Gender Division of Labor in Noakhali District

	Women	Men	Both
Private Domain	• Child care • Domestic tasks • Livestock and poultry rearing • Homestead gardening • Post-harvest tasks • Seed preservation • Subsistence agricultural tasks • Collection of biomass within homestead	• Building the house • Preparation for strengthening the house before the potential rain/ cyclone periods • Fishing in adjacent ponds	• Water fetching • Weaving • Fish processing • Domestic management during disasters
Public Domain	• Collecting cow dung and other biomass • Domestic maids • School teaching • Egg selling by children	• Farming • Fishing • Trading • Day labor • Rickshaw pulling	• Day labor • Industrial labor • Agricultural labor • Small trading • Fish selling at market • Commercial vegetable production • Milk selling services

Wage Rate:

Today, though not comparable with their male counterparts, women are participating in the labor market, but there exists high wage rate disparities between men and women. Wage rates are different over different seasons, depending upon the demand for labor. In rural areas the wages reach their peaks during the transplantation and harvesting periods of main crops (such as T. *Aman*). In *char* areas the wage differences are even greater.

Access to Resources:
Women's access to resources in Nakhali is mostly confined to the domestic domain (domestic utilities, cattle, homestead and adjacent ponds), it is often only when they go to fetch drinking water from a distant tubewell that they leave the domestic domain. Some women have inherited landholdings (either from their father, or in case of widows from their husband), but in most cases the women do not have the right to make decisions on the usage of these resources, whether to retain them and how to use them, or to sell them. Social expectations, family values and laws all affect women's access to common property resources, infrastructure and formal and non-formal institutions. Women's claim on household resources is also secondary to men's which undermines their contributions to sustainable livelihoods.

In terms of access to financial resources, hardly any women in Noakhali go to the Krishi Bank or other banks and apply for loans. Only non-governmental organisations (NGOs) sometimes support them with micro-credit, although this is still uncommon. It is the norm that the male member of the household (father, husband, brother) has the control over this money anyway, so it is difficult to assess whether the increased access to borrowing from NGOs alone can improve women's access to financial resources or enhance their participation in private/family decision making processes. The question of who controls the resources is vital.

Access to Health Care, Safe Water, and Sanitation:
It is mainly women who take the responsibility for collecting water. Those households that do not possess tubewells have to fetch water from distant households, adjacent schools, madrasas, the district board office etc. Women and childrens face tremendous problems collecting drinking water all year round. It is often dangerous when women have to go outside for water at night. There is also a risk of arsenic poisoning and people do not use those tubewells on which the Department of Public Health Engineering (DPHE) has put red marks.

The health of women, especially those who live in *char* areas, is in a poor state. Many women never visit a doctor in their lives and their attitude towards medication is negative. Most of the women in char areas would not consult a doctor unless there was a severe emergency. In the case of childbirth, almost every family prefers delivery at home with the help of their female relatives. The sanitation situation is very poor; almost every house in *char* areas uses a *kutcha* latrine which is unsanitary. According to these people, sanitation is the most neglected area for them.

Social Insecurities in *Char* Areas
The construction of embankments (*beribadh*) is a symbol of both environmental and social security for the people of *char* areas although people living on and outside *beribadh* are less secure than the people living within them. People outside the embankments are often attacked by local terrorists.When women have to go outside for various purposes like fetching water etc. they feel unsafe. People outside the embankments tend to be poorer as they are more vulnerable to disasters without the protection that those living inside the embankments have.

Conclusions and Recommendations

Climatic Trends

The analysis of local temperature data shows an increasing trend of annual average temperature of the study area. It has been noted that 7 out of the 10 hottest years on record have occurred since 1990. Rainfall during monsoon season shows no apparent trend, however it appears that variability of rainfall in recent years has increased. Also, the wettest and driest monsoons are increasingly on record in recent times.

Life and Livelihood

Climate change may affect the coastal region through salinity, erosion, accretion, floods, waterlogging, cyclones and tidal surges. Livelihoods of people have been affected through the impacts of climate change on agriculture, fishing, livestock, shrimp farming, off-farm activities and even the locations of human settlements. Over the centuries, climate variability and extreme weather events have caused damage to people's lives, assets, resources and livelihood practices, which eventually have led people to devise indigenous coping strategies for survival. The practiced coping mechanisms within the communities and their traditional knowledge-base enable them to organize at the community level and manage disasters. Even their wealth of knowledge regarding the management of their livelihoods in different changed climatic scenarios is found to be substantial.

The study area suffers tremendously from waterlogging which is expected to be aggravated with the change of climatic patterns. Arguably, the best coping potential lies in moderation of the physical risk factors. For the prevention of waterlogging, proper drainage systems and housing planning must be ensured. For this, local government can initiate different measures to drain out the water due to excessive rainfall and to structure a planned township.

Other than waterlogging, droughts, cyclones and salinity are the most devastating phenomena in Noakhali district. To cope with cyclones, adequate multipurpose cyclone centers can be built. To renovate or rebuild the dwellings as a protection from cyclones, soft-term loans can be disbursed to local people. To cope with drought and salinity, research must be carried out in the agricultural sector to develop crop varieties (especially rice varieties) which can tolerate these conditions.

Agriculture

Simulation studies have shown that the climate change impacts could result in significant reductions in crop yields, in most cases, and therefore production. The effect of the changes would vary because of the differences in the crop varieties and local differences in growing seasons, crop management etc.

As the incidence of floods and droughts is likely to increase in frequency, effort should be made to develop crop varieties tolerant to these conditions. On the other hand, agronomic manipulations such as shifting the planting dates, using short duration crop varieites could be other options. During the dry months of March and April, salinity problems, resulting from seawater intrusion, are more acute and lands are commonly left fallow as crop production is restricted by the presence of salt. Cash crops such as tomatos and chilies can be grown with proper management of soil and water. Use of raised beds and irrigation through drip irrigation systems permit proper leaching of salt from the root zone. This system of crop cultivation produces high economic benefits compared to traditional methods.

Improvement in the crop-based weather and flood forecasting systems is one of the adaptation measures that is urgently required. Early warning systems should be strengthened to inform the farmers about their roles in an adverse weather condition on the basis of specific information analysis. The Department of Agricultural Extension (DAE) provides "extension messages" on the basis of agro-meteorology and agro-climatic data, and forecasts the sowing/transplanting time and possible yields of crops to the farmers.

Fisheries

The potential impacts on coastal fisheries may include: (i) loss of coastal inland fisheries; (ii) further changes in species composition, particularly due to inundation of coastal areas; (iii) loss of fresh water culture fisheries due to storm surge-related tidal bores and salt water inundation; (iv) changes in fishing methods and gear; (v) declined *hilsa* fishery due to changes in migratory routes; and (vi) loss of shrimp farms, etc. However, there could be increased fish production from marine fisheries.

The present coping strategies practiced by the community and supportive activities undertaken by various agencies for combating the adverse impacts of climate induced disasters are probably not adequate to address the full range of present and potential impacts in the future and therefore would require some additional adaptation in future. With the participation of local people, a range of future adaptation needs are identified, which are as follows: (i) improvement of fish habitats; (ii) promotion of mechanization of boats for fishing in the sea; (iii) further promotion of scientific pond aquaculture; (iv) introduction and promotion of community-based *doghi* culture; (v) development and promotion of culture of salt tolerant fish species; (vi) strengthening of evacuation system and awareness building; (vii) increasing of embankment heights; and (viii) construction of cyclone centers in newly formed char lands.

Fishing Boats

It has been found that poor structural strength of the boats is the principal reason for the accidents involving fishing boats. The poor strength is caused by the use of poor quality timber, poor construction and improper maintenance. The second but far less important reason is the poor condition of the engine and equally poor maintenance and operation. However, all these are the direct result of lack of availability of market finance for the sector and it hardly needs mentioning that most of the boat owners, especially in the study area, are poor. There are other factors such as inadequate life savings and communication equipment, absence of navigation aid etc. Improvement in these matter would either contribute to reduction of human casualties in such accidents or avoid the hostile situation altogether.

Housing

Instead of designing a proto-typical model house to be indiscriminately replicated without paying heed to context, it was conceived wise to recommend “Building-for-Safety (BFS) Options”. These are modest technological innovations that would contribute towards improving the performance of existing housing types by strengthening or improving parts of the house, which are particularly weak and vulnerable in the local climate.

Because of the coastal location, houses need to be built to withstand strong wind. Perhaps the nature of rural housing would not permit it to withstand a severe cyclone, but strengthening the house structure would at least provide resistance to the frequent strong winds and storms. The roof is particularly exposed to damage by wind and this building aspect requires careful attention by incorporating strengthening techniques within local means. There is a need for trained, village-level house building specialists – “para-architects” or “barefoot engineers” – for replicating, disseminating and sustaining within the community new construction methods that are introduced. Key people at the community level should be trained for this purpose.

Institution

The local level institutes need to be equipped with climate change knowledge so that they can help the local people in adapting to the change. Engineering related local level institutes have technical people and are capable of incorporating climate change into their design provided there is higher level decision making and funds are available. It is also important to note that changes in infrastructural design need local level data and information of climate change impacts on different infrastructures. Awareness raising and targeted capacity building for different groups is necessary to promote rural development and livelihoods of the local community. Incorporation of climate change issues in the sectoral policies and institutional mandate for awareness raising at senior level (decision makers) is equally important.

Glossary

- *Aus* rice: This is a periodically fixed maturing, photoperiod-insensitive group of rice. In Bangladesh this crop is mainly rainfed and dry-seeded but when sufficient rainfall or irrigation water is available the crop is also transplanted. Seeding of this crop is done during March to April with the beginning of pre-monsoon showers, and harvesting is done during July to August, in mid-monsoon. Transplanting is generally done a little later than the dry-seeded crop.
- *Boro* rice: Photoperiod insensitive winter season irrigated rice transplanted in December to January and harvested in April to May.
- *Kharif* season/crops: Monsoon season, i.e. from April to September in Bangladesh which is known as the kharif season. Crops grown during this time are known as kharif crops. Examples are *Aus* rice, *Aman* rice, and jute.
- Mudflats: Newly formed land, mainly silty to clayey in texture.
- *Sorjan*: A system of cropping in the wet land or waterlogged area on artificially made alternate raised beds and ditches.
- *Upazila*: An administrative unit in Bangladesh comprising several 'unions' which, in turn, are composed of several villages.
- Transplant (T.) *Aman*: A group of traditional photoperiod-sensitive rice varieties transplanted in July to August and harvested in November to December. In Bangladesh today, photoperiod-insensitive varieties are also available and farmers are also growing these during T. *Aman* season.
- *Khas* land: Government owned land
- *Char* land: Newly formed island

Bangladeshi and English Year and Seasons

GRISHHO		BORSHA		SHOROT		HEMONTO		SHEET		BOSHONTO	
Boishak	Joshtho	Ashar	Srabon	Bhadro	Ashwin	Kartik	Agrahan	Poush	Magh	Falgun	Choitro
April-May	May-June	June-July	July-August	August-September	September-October	October-November	November-December	December-January	January-February	February-March	March-April
SUMMER			AUTUMN			WINTER			SPRING		

Reducing Climate Change Induced Risks and Vulnerabilities from Glacial Lake Outburst Floods in Bhutan

Karma, Y. Dorji, D. Wangda, I. Tellam

Introduction

There is a growing scientific consensus that anthropogenic induced climate change has been occurring since the beginning of the industrial revolution. Impacts of climate change are felt all around the world, particularly in climate sensitive regions with vulnerable ecosystems. For instance, shortage of water resources due to the retreating and shrinking of glaciers and hazards related to Glacial Lake Outburst Floods (GLOFs) are serious climate change impacts felt among the communities residing in mountain environments. Given the sensitivity of mountain environments, especially the cryosphere, ever-rising air temperature has serious consequences for natural and socio-economic systems in the area.

A major proportion of Bhutan's population is settled in fertile valleys along a number of river systems. When GLOF occurs along rivers which are sourced from glaciers and glacial lakes the lives and property of many people are at risk. Such devastating effects can still be seen today from the last GLOF that took place in Bhutan in 1994 along the Puna Tsang Chu valley. Not only are lives and property endangered but also important infrastructure such as hydroelectric dams that are situated along these rivers. If Gross National Happiness1 is the pride of the Bhutanese people then the driving force behind it is the hydroelectric power stations, which are driving the Bhutanese economy forwards with a contribution of about 45% to national revenue and 12% to GDP growth.

The Government of Bhutan has taken a step towards adapting to climate change by developing a National Adaptation Program of Action (NAPA), coordinated by the National Environment Commission (NEC). The main objective of the NAPA has been to identify and address the most prominent issues related to climate change. Three projects from the Bhutan Department of Geology and Mines have been prioritized during the NAPA formulation. These are: artificial lowering of lake water level in the Thorthormi lakes; installation of early warning systems in Punakha-Wangdi valley; and hazard zonation mapping in Chamkhar.

The Netherlands Climate Assistance Program (NCAP) supported a GLOF hazard zonation mapping exercise along the Puna Tsang Chu from Khuruthang to Lhamoizingkha. This project was not listed under the NAPA projects but was nevertheless considered important because: i) a hazard zonation map already exists from Lunana (source) to Khuruthang in Punakha, which was completed as part of an earlier Austria-Bhutan project; ii) a number of planned large hydroelectric power schemes are situated on the Puna Tsang Chu; and iii) earlier studies with Austrian and Japanese researchers demonstrated that lakes in Lunana still pose GLOF threats and recommended that hazard zonation mapping be carried out in this area.

1 http://www.grossnationalhappiness.com/

Objectives

During the joint project between the Department of Geology and Mines with the experts from the University of Vienna, Austria, a hazard zonation map was prepared from the source of the Pho Chu to Khuruthang in Punakha. But the remaining area between Khuruthang and Lhamoizingkha remained an area without a hazard zonation map for Glacial Lake Outburst Flood (GLOF). A need for similar maps for the remaining area was realized considering the following reasons:

- The presence of critically dangerous glacial lakes at the source of the Pho Chu;
- The large number of settlements along the fertile valley bottoms along the Puna Tsang Chu;
- Large hydropower plants which both exist and which are in the pipeline on the Puna Tsang Chu; and
- Other developmental infrastructure along this river valley.

Therefore the main aim and objective of the DGM-NCAP project is to prepare a "hazard zonation map" from Khuruthang in Punakha to Lhamoizingkha on the Bhutan-India border under Dagana Dzonkhag, thus covering the entire area along the Puna Tsang Chu with a hazard map for GLOFs in the future. These maps are expected to serve as a tool to guide the planners and decision makers:

- As a tool for any future developmental activities along this river; and
- As a guide for the local communities and local authorities to minimize the damage on the lives and properties of the people.

Material and Information Used

For the purpose of data analysis and hazard map production the following materials used are:

a. Topographical maps
Topographical maps for most of the areas where accessible and critical were prepared using surveying instruments ("Total Station"). The close contours generated were then used for the data analysis. For those parts where the accessibility was not possible, the contours generated from the SRTM were used. In fact the slope which forms one of the important aspects in the data analysis part was generated using these contours.

b. Satellite images
Given the importance of the project, a set of Quick Bird images were procured which have a resolution of 0.6m.

c. Land use maps
These maps were prepared in the field based on the field verification and using the satellite images as base material.

d. Material maps
These maps were also prepared in the field based on the field verification and using the satellite images as base material.

e. Slope maps
For the areas which were accessible and critical, surveys were conducted using "Total Station" and contours generated from this were then used to generate the slope maps. For those areas where it was inaccessible for the team to conduct surveys, SRTM was used to generate contours and based on these contours slope maps were prepared.

f. Socio-economic information
All this information was collected in the field through interaction with the local vulnerable communities. The information covers a wide range of aspects which are listed below. This information was mainly collected to assess the vulnerability of the local communities should a GLOF occur in the Puna Tsang Chu basin.

Methodology

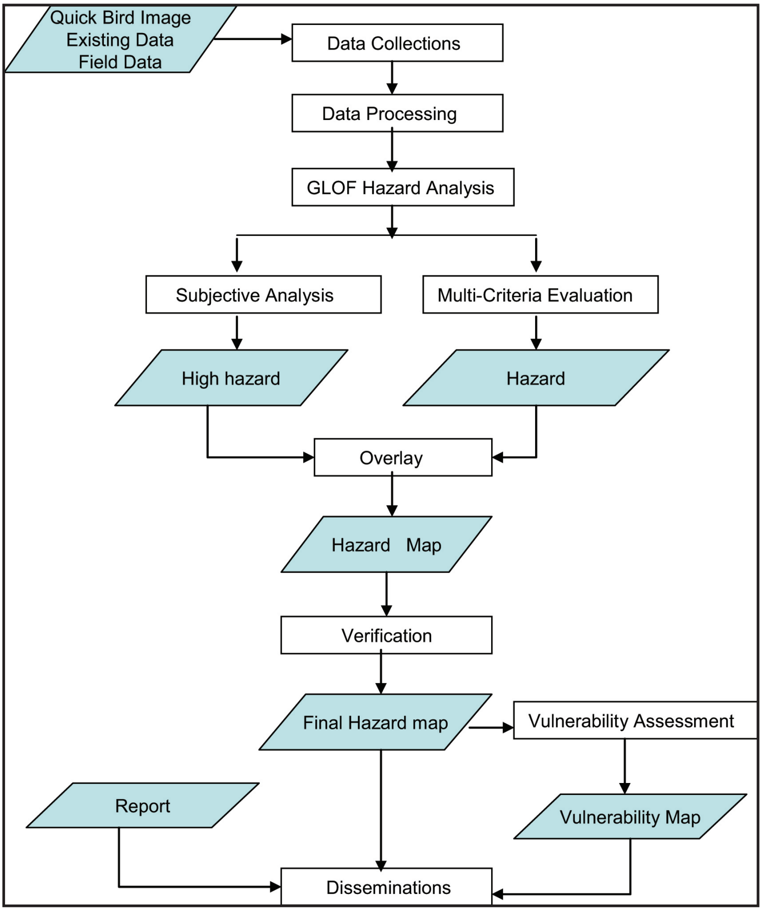

Figure 1: Overview of the Methodology

An overview of the methodology used in the preparation of hazard maps is shown in the above figure (figure 1). The whole process of the preparation of the hazard maps was kept very simple but all the technical aspects required were incorporated. Each of the steps followed in the above figure are explained in detail in the following section.

Data Collection

The data and information which were required for GLOF hazard zonation analysis and vulnerability assessment along the Puna Tsang Chu were collected through various means such as from existing data, field surveys and remote sensing data (Quick Bird images).

a. Remote sensing data

The Quick Bird images were procured to derive or extract the features and information which were necessary for GLOF hazard zonation and vulnerability assessment. There are three levels of quick bird image products: basic imagery, standard imagery and orthorectified imagery. For this project standard imagery was used. The standard imagery products were radiometrically corrected, sensor corrected, geometrically corrected and mapped to a cartographic projection and had a resolution of 60cm. Furthermore, the GPS observation in the project area was carried out for geo-rectification of the image to enhance the accuracy. The infrastructure and utilities which were extracted from the image included industry, public buildings, commercial buildings, residential buildings, government institutions, schools, roads, footpaths, bridges, historical monuments, power lines and telecommunication lines etc. The quick bird images were not only used for the above feature extraction, it was also used for the extraction of material type and land use.

There are various ways of extracting the feature from the image. In this project, visual interpretation and screen digitization was used applying geographic information system (GIS) and remote sensing (RS) technology. The GIS and RS offer appropriate technology for data capture, data integration, data management, storage, information extraction, routine manipulation, spatial analysis, decision making and visualization. They also offer strong tools to assess different hazards, risk, vulnerability, damage and much more. The extracted features were checked during the ground verification and updated.

b. Field survey data.

For assessing the impact of future GLOFs, the detailed socio-economic survey in the entire project area and the topographical (mainly contour line) survey using "Total Station" were carried out in the places where there are human settlements, development and the elevation is lower than the river. The data for the socio-economic survey consisting of infrastructure, population and livestock was collected from every household and recorded in the GIS format. The 1994 flood marks were also collected for validation and subjective analysis.

The socio-economic data collection was confined to settlements within a 250m buffer zone on either side of the Puna Tsang Chu. The existing data is the data and reports that are available through government agencies.

c. Existing (available) data

The existing data is the data and reports that are already collected and available with the various agencies:

1. Aster DEM (15m), Department of Energy
2. Administrative boundaries (Survey of Bhutan)
3. Topography Map 1:50,000 (Survey of Bhutan)
4. Reports on GLOF
5. Lake volume

d. Data processing

This is the preparation of spatial data for processing, the analysis required by the operating system graphically, or storage and processing of data by the computer using particular software. Data processing or information processing was performed on data in accordance with strictly defined procedures for a certain application, these included: i) conversion of data into a form that can be processed by the computer; ii) storing or processing of data by a computer; and (iii) data handling, merging, sorting, and computing.

The meta data was also collected for the existing data and analyzed. The information on the quality of spatial data allows users to determine a product's ability to satisfy the requirements for his/her particular application.

e. *Spatial data analysis (GLOF hazard analysis)*

In this project, the GLOF hazard analysis was carried out with the combination of two methodologies namely a *subjective analysis and multi-criteria evaluation*. The detail of each of methodology is described below.

Multi-criteria evaluation is primarily concerned with how to combine the information from several criteria to form a single index of evaluation. In the case of Boolean criteria, the solution usually lies in the union (logical OR) or intersection (logical AND) of conditions. However, for continuous factors, a weighted linear combination is a usual technique. As the criteria are measured on different scales, they are standardized and transformed such that all factor maps are positively correlated with floods. Many decisions depend on identifying relevant factors (criteria) and adding their appropriately weighted value. Each expert in a decision or in the process of weighting criteria will have their own assessment of it based on their knowledge and experiences.

An ArcGIS Model Builder, commercial GIS software produced by ESRI has been used for this project of a GLOF analysis. A multi-criteria evaluation can be approached from two methods: a) binary method and b) weighted overlay method.

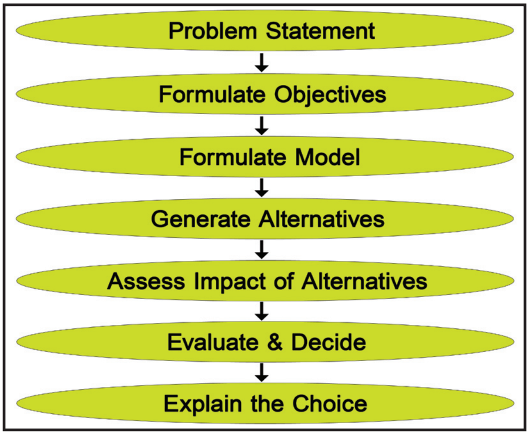

Figure 2: Multi-Criteria Evaluation Process

The purpose of the criterion weighting is to express the importance of each criterion relative to other criteria. The more important criteria had the greater weight in the overall evaluation. In this project two ranking methods were introduced and applied. Namely binary analysis and weighted overlay analysis. GIS should act as the interface between technology and the decision maker with integration MCE method onto the GIS. Different decision makers' maps apply different criterion and assign different weights for each criterion according to their preferences. The decision maker selects the criteria and compares them in a comparison matrix.

In multi-criteria evaluations, the preferences of the decision-maker are accounted for by the weighting placed on each of the criteria and sub-criteria. These weightings may range from equal importance of all criteria, to a ranking of most to least important or to a relative weighting of all criteria. The weights may be qualitatively expressed, quantitatively expressed or a mixture of both. In analyses which involve many different decision makers, this can be the most important and informative part of conducting the whole process. It allows stakeholders to express differing views explicitly and it helps identify those areas which are of most importance to them and which warrant careful investigation. When more than one decision-maker is involved (a so-called "5 group decision"), the process becomes more complex and controversial as now the preferences or weights are not unique but variable among the participants of the decision process. This process leads to a compromise decision making. A multi-criteria evaluation can be approached from two methods namely a) binary method and b) weighted overlay method. However, we have adapted the weighted overlay method for GLOF hazard analysis since it has some advantages over the binary method.

The binary method shows an impact function of the individual criterion with suitable layers for each of the separate criteria. The individual layers use "suitable" (1) and "non suitable" (0) or true and false. It is done by performing a simple map algebra using an AND operator. The result of this model ranges from 0 to 1 with many classes in between. In this model, the above mentioned criteria were implemented and came out with a most suitable, a suitable and a not suitable area for mining. The disadvantages of binary approach and results are shown as follow:

- The input layers have the same importance; and
- There is nothing in between suitable and not suitable.

The *weighted overlay method* is a technique for applying a common measurement scale of values to diverse and dissimilar inputs to create an integrated analysis (http://webhelp.esri.com dated 06-12-07). Weighting should be applied when not all aspects have an equal importance. It should be realized that the choice of a weight is most important, as it has a great effect through multiplication of the scores.

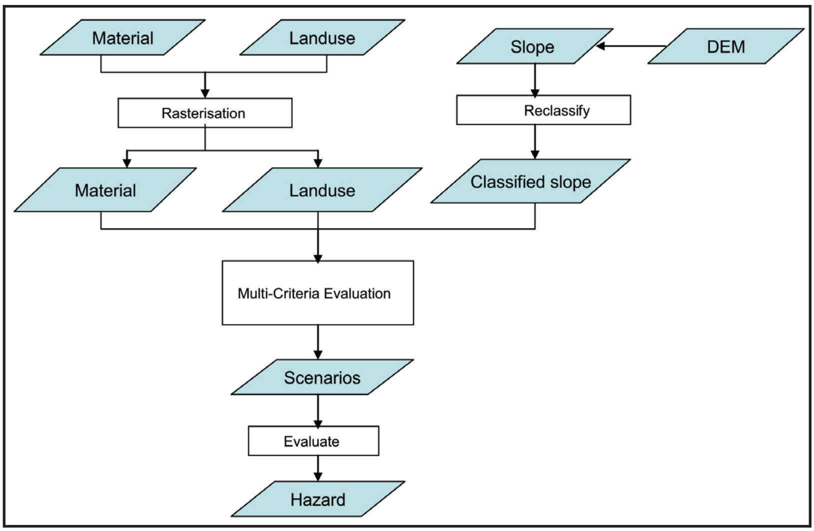

Figure 3: Work Frame of Weighted Overlay Process

Assigning the weights to factors is a critical element in suitability analysis. Weighting factors are often based on a mixture of implicit knowledge, personal experience and individual opinions. In order to reduce the subjective bias as much as possible, this research will use three weighting methods based on three different considerations in the study area.

Figure 3 shows the work frame of weighted overlay for GLOF hazard analysis to produce GLOF hazard maps.

In the process of multi-criteria decision making (MCDM), different stakeholders in the design process have different views about what is important, how that importance should be measured, and how various important factors can be combined. In multi-criteria evaluation, the important components are the weight and priorities assigned to each criterion which are weighted on quantitative measurement scales. The weights are applied or assigned to criteria when not all the aspects have equal importance in the evaluation. In the study the criteria have unequal importance so the weights have to be assigned to each criterion and this depends on evaluator opinion and decision makers.

The GLOF zonation mapping along the Puna Tsang Chu was carried out using a GIS based multi-criteria evaluation method taking the following causative factors:

- Land use/land cover;
- Type of soil/material along the river;
- Slope;
- Horizontal distance from river; and
- Height of river terraces.

The factors such as height of river terraces and horizontal distance from river were not used in the actual process of multi-criteria evaluation but were used in the editing process.

Considering an evaluation scale range of 1 to 3 (1- low hazard, 2- medium hazard, 3- high hazard), these causative factors were then assigned with different weights based on the importance of each factor in the events of GLOF. The weighted overlay process combines different types of data by assigning evaluation scale values and the amount of influence to the values in each thematic map.

Field Verification

Once our results are obtained from any spatial analysis, it is essential that they are verified. After the completion of hazard analysis, a team comprising a Glaciologist, Geologist, Geo-Informatics officer and survey assistant went into the field to carry out the field verification on the ground. The population and infrastructure data, land use/land cover, material type, terrace height and horizontal distance from the river centre were taken into account during ground verification. Not only were these taken into account, but also the historical data of GLOF events in the past particularly the 1994 GLOF and the information collected regarding the past GLOFs from the people. It was found that the results obtained were as good as could be expected.

Sensitivity Analysis

This is a discipline that plays a key role in the scientific modeling. It is the study of how the variations in the output of a model are apportioned qualitatively or quantitatively to different sources of variation of a model. The number of input factors involved in the analysis and objectives of the model play a major role in determining the final result. A sensitivity analysis on a model is to identify a parameter which has a substantial impact on a final result. A model which was created for suitability for a mining area in Bhutan was run to evaluate the impact of parameters. Sensitivity analysis depends on the error in the input data as criterion weights and criterion attributes. The impact of parameters on the final results was tested using sensitivity analysis and it was found that both land use and material had equal influence.

Setting

“The Land of the Thunder Dragon”, “The Last Shangrila” and the “Land of the Peaceful Dragon” all refer to the tiny kingdom of Bhutan nestled in the eastern part of the Great Himalayan Range. Located between the two giants of China in the north and India on the remaining three sides, Bhutan is populated with just over 600,000 people. The terrain is mostly rugged and mountainous with altitude ranging from less than 100m in the south to more than 7,500m in the north within a north-south distance of less than 175km. 20% of the land area is above 4,200m and permanently covered with snow and ice, which form glaciers and glacial lakes.

The climate is dominated by the southwestern monsoon that originates from the Bay of Bengal. Normally the monsoon sets in the mainland by early June and last till early September. Just after the monsoon during the months of October and November, occasional rains occur which are basically the post-monsoon rains and can be quite severe. From November to March the period is usually dry but sometimes light showers may occur from the westerly winds, which brings rain to the foothills of the Himalayan range. The pre-monsoon season falls in the months of April and May which are accompanied by light showers, lightning and hailstorms. The record shows a rainfall of approximately 2,500 to 5,500mm in the southern foothills, 1,000 to 2,500mm in the inner valleys and 500 to1,000mm in the northern flank of the country. Climatically, the country can be divided into three zones: subtropical in the southern foothills; temperate in the middle or inner valleys; and alpine in the northern part.

All four seasons can be experienced in the country characterized by hot and humid in the southern foothills during summer and cool in winter, the middle valleys are warm in summer and cold in winter with pleasant spring and autumn with mild temperatures. Overall the variation in the climate is dominated by the altitudinal change.

Most of the rivers in Bhutan flow from north to south. The country is drained by five major river systems namely the Amo Chu, the Wang Chu, the Puna Tsang Chu or Sunkosh, the Manas, and the Nyere Ama Chu with many tributaries which are of appreciable size. Except for the Amo Chu and the Nyere Ama Chu the remaining three major rivers are formed by the joining of a number of tributaries. The Wang Chu is a collection of three main tributaries namely the Pa Chu, Ha Chu and Thim Chu. The Puna Tsang Chu or Sunkosh is formed by the amalgamation of another three main tributaries namely the Pho Chu, Mo Chu and Dang Chu. Similarly the Manas river system is a collection of another four major tributaries, the Mangde Chu, Chamkhar Chu, Kuri Chu and Dangme Chu. Almost all these rivers have their source in the perpetual snow and ice in the northern frontier of the country except for Kuri Chu which is a trans-boundary river having its source in China.

The impact of climate change is felt globally. It is projected that spatial average annual mean warming over the Asian region will be about 3°C by 2050 and about 5°C by 2080s as a result of the continued emissions of green house gases.

But what exactly is happening? Little research and studies have been done along the Himalayan Arc in terms of climate change, making it one of the least researched places in the world with scarce climate related data.

Some anecdotal evidence exists of impacts experienced by people living in the high altitude region of Manang and Mustang districts of Nepal. This includes recent erratic patterns and intensity of rainfall, which has impacted livelihoods to a great extent affecting houses built with traditional technology, fresh water resources and the agriculture sector, which basically depends on the availability of water at the right time. Declining Himalayan grassland due to low moisture content induced by less snow fall and snow cover in the mountain areas, has affected livestock adversely. Some locals feel that emerging mosquito related problems in places located above 2,700m may have been due to climate change. This anecdotal evidence seems to correlate well with the available scientific evidence and predicted scenarios.

As mentioned above climate data in the Himalayas is very scarce but studies on the analysis of available data in the Nepal Himalayas shows that the temperature is rising at an alarming rate. The warming seems to be consistent and has continued since the mid-1970s and average warming between 1977 and 1994 was found to be 0.06°C/year. It was also observed that the warming seems to be more pronounced in the higher altitudes in the mountains than low lying plains. A similar trend was also seen in the Tibetan Plateau.

Impact on the Himalayan Cryosphere

It is estimated that there are over 18,000 glaciers mainly concentrated in the following five major river basins: Lake Mapam Yumco; Ganga River basin; Yarlung Zangbo River basin (Barmhaputra); Indus River basin; and Sutlej River basin.

The huge field of ice and snow reserve supplies over 8.6 x 10^6m^3 of water annually, the region is called the "water tower of Asia". The Himalayan Arc, considering its vast regional extent is home to millions of people with diverse cultures, lives and languages. The perpetual snow and ice fields in the Himalayas play a vital role in the socio-economy of the people living in the fertile valleys of this astounding mountain range, all establishing an ecological balance. The inhabitants of this region, who have traditionally lived in a delicate balance with their surrounding environment, are beginning to experience the impacts of climate change.

The glaciers in the Himalayan region are classified as the "summer accumulation" type, which implies that the glacier accumulates during the summer from the summer monsoon when ablation occurs simultaneously, making them very sensitive to changes in air temperature. A number of studies around the world show that the mountain glaciers are retreating. But across the Himalayas studies show that the glaciers are found to be shrinking more rapidly than the glaciers in other regions of the world and the retreating and shrinking has accelerated in the recent decades. The following section gives an overview on the retreating glaciers across the Himalayan Arc.

Shrinkage of 5.5% was observed in China's glaciers over the last 24 years according to a study by the Chinese Academy of Science. *China Daily* (23rd September 2004) stated that as per the studies two thirds of the glaciers in China would disappear by the year 2050 and almost all by 2100 if the present trend of climate change continues. Within 12 years in Poiqu River basin there was shrinkage of 5.04% in the glacier area. The glacier valley in the Xixiabangma Mountains have retreated by 45m and 68m respectively since 1977.

Many studies were carried out on the fluctuation of glaciers in the Indian Himalayas Significant changes (retreat) were recorded in the last three decades.

When it comes to glaciological research activities in the Himalayas, the Nepal Himalayas are some of the most extensively investigated stretches across the Great Himalayan range. Most of the results show that the glaciers are retreating at a remarkable rate in the latter half of this century.

Glacier Lake Outburst Floods (GLOFs)

Fast decaying (retreating) glaciers leaving behind large debris of loose moraine with the formation of lakes behind it. These lakes grow in size with time and are dammed by unstable moraine ridges. These lakes could burst under various circumstances causing devastating floods in the downstream area, popularly known as Glacial Lake Outburst Floods (GLOFs). The impact of such floods on the lives and property of the people and infrastructures can be significant. In the Himalayan region it has been observed that the frequency of occurrence of GLOFs has been on the rise since the last half of the 20th century.

Cases of GLOFs were reported from almost all regions of the Himalayas, for example the 1985 Dig Tsho GLOF, the 1998 Tam Pokhari GLOF in Nepal; the 1964 and 1981 Zhangzangbo GLOFs in China and also the 1950s, 1960s and 1994 GLOFs in Bhutan. Besides these there were also cases reported from Pakistan. All these events caused huge damage to infrastructures of national importance and property and also resulted in loss of lives of both livestock and people.

National Economic Loss

The fast flowing rivers in countries like Nepal and Bhutan have a huge potential for hydropower generation. Being landlocked in terms of geographical locations, the national economy relies on hydropower generation (especially in the case of Bhutan where hydropower stands first in terms of national revenue generation). The long term impact of glacier retreat on river runoffs would be a disaster for such nations. Major industries which rely on river and stream water supply such as chemical, steel, paper and mining industries would be seriously affected. The water sensitive agriculture sector will be another major sector affected which may lead to serious consequences on crop production and consequently food security.

Climate Change and Natural Hazards in Bhutan

Bhutan, considering its geographical location and geological settings is prone to a number of natural hazards such as GLOFs, flash floods, landslides etc. The history shows at least three cases of GLOF in the past the most recent one being the 1994 GLOF from Luggye Tso. Flash floods have become a common phenomenon across the country. The most destructive one was the one that occurred in Pasakha, an industrial estate under Chukha *Dzongkhag* (district) in southern Bhutan in 2000. More recent flash floods include the one in Ranjung and the surrounding events in the eastern part of the country from which the country, is still in the process of recovering. Landslides blocking roads in the Himalayan region is not a new phenomenon but when whole villages are destroyed by progressing landslides or huge artificial lakes are being created by landslides, the risk posed can be a major national catastrophe. Such events has been witnessed in the eastern part of Bhutan like the Moshi landslide under Trashigang *Dzongkhag*, the Chaskhar landslide under Mongar *Dzongkhag* and the Tsati Chu artificial lake created by the landslide upstream in the Kuri Chu on which a 60 MW hydropower (KHPC) existed. The country has experience almost all types of mountain hazards in the past.

Now, with the impacts of climate change, the frequency of such natural hazards has increased tremendously and a new threat in the health sector has appeared in recent times. Already the climate related health problems such as outbreaks of dengue fever and malaria related problems are on the rise in southern Bhutan. *The Bhutan Times*, a weekly newspaper, reported a rising trend of dengue fever cases in southern parts of the country.

Another article from the same weekly paper reported unusually high temperatures in Phuentsoling and Gelephu town in southern Bhutan. During July and August 2006, summer temperature in Thimpu (approximate altitude 2,200m above sea level) reached 40°C and 33°C . Due to the intense heat there were some incidents where schools were closed down especially in southern Bhutan. The report also highlighted the decrease in rainfall throughout the country during this particularly hot summer.

Likewise there are more signs of climate change impacts seen in Bhutan recently. The impacts of climate change are usually associated with destruction but sometimes it can also be a positive shift for local communities. For example, Bumthang *Dzongkhag* in central Bhutan is located at an altitude of about 2,750m above sea level, and has never seen paddy cultivation in their district. But recently the Ministry of Agriculture (MOA) conducted a trial observation with positive results. Similar trends were also reported from the high altitude regions of Nepal.

Project Site

The project area lies in western Bhutan starting from Khuruthang in Puna *Dzongkhag* to Lhamoizingkha in southern Bhutan on the Bhutan-Indian border under Dagana *Dzongkhag*, covering a distance of approximately 180km with an altitudinal variation of 1,800m in Punakha to less than 100m in Lhamoizingkha. The area covered in our project includes part of Punakha, Wangduephodrang, Tsirang and Dagana *Dzongkhag*.

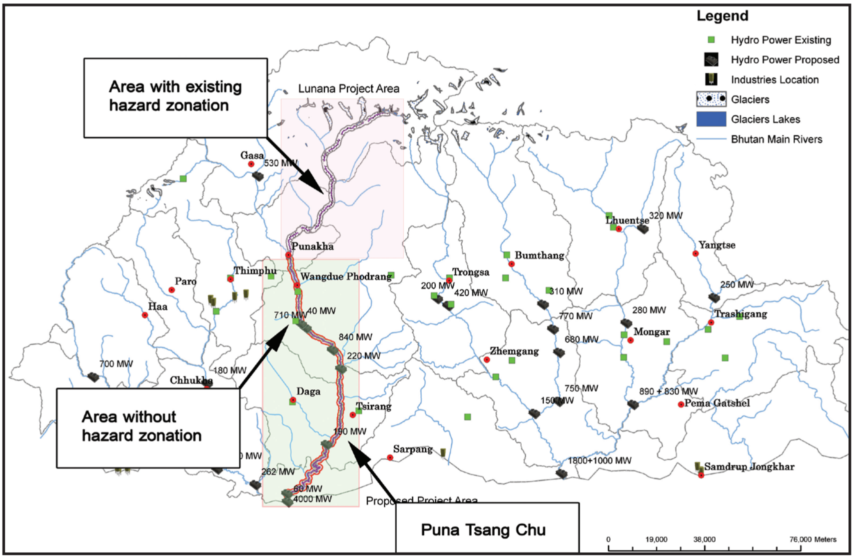

Figure 4: Map Showing the Project Area

Glaciers and Glacial Lakes in the Headwaters of the Project Site

Pho Chu and Mo Chu are the main tributaries, which join at Punakha to form the Puna Tsang Chu. Both of these tributaries have their source in the glaciers and glacial lakes in the northern part of the country. Further downstream at Wangduephodrang, the river is joined by another tributary called the Dang Chu which has it source mainly from the collection of mountain streams further up the Sha Valley.

Status of Glaciers in the Headwaters of the Puna Tsang Chu

As already mentioned in the previous section, there are quite a number of glaciers and glacial lakes present in the Puna Tsang Chu river basin where our DGM-NCAP project has been implemented. Considering the high sensitivity of glacial environments to any changes in the climate system it is important to know what is really happening to these glaciers and the lakes in the headwaters of the Puna Tsang Chu. The results from our earlier studies and observations are discussed in the following section.

Glaciers in the Himalayas are of two types based on their formation and whether they are clean type (C-type) or debris covered (D-type) glaciers. The Himalayan glaciers are also classified as "summer accumulation" types. The D-type glaciers are considered less sensitive to climate change since they have a mantle of debris deposited on their surface. On the other hand the C-type glaciers with their clean surface are considered to be quite sensitive to any changes in the climate, especially the temperature.

A ground survey was conducted on a C-type Jichu Dramo glacier, a small clean type glacier in the same basin in the Bhutan Himalayas as a part of field activities under the joint Japan-Bhutan research project in 1998 and resurveyed in 1999 to assess the changes. The results and the work details reported a 12m retreat (from 1998 to 1999) with a rough estimation of 2 to 3m in surface lowering.

The retreat rates for the C-type glacier in the Bhutan Himalayas were compared with the retreat rates for some of the glaciers from east Nepal. The result was that the retreat rates are higher for the glaciers in the Bhutan Himalayas than the glaciers in east Nepal, which confirms the sensitive nature of glaciers to the intensity of the monsoon.

In addition to the retreat rate the authors also computed aerial shrinkage for 66 C-type glaciers in the Bhutan Himalayas for a period of 30 years. The glaciers occupied an area of 146.87km^2 in 1963 but this area decreased to 134.94km^2 by 1993. This is about 8.1% aerial shrinkage within a time span of just 30 years.

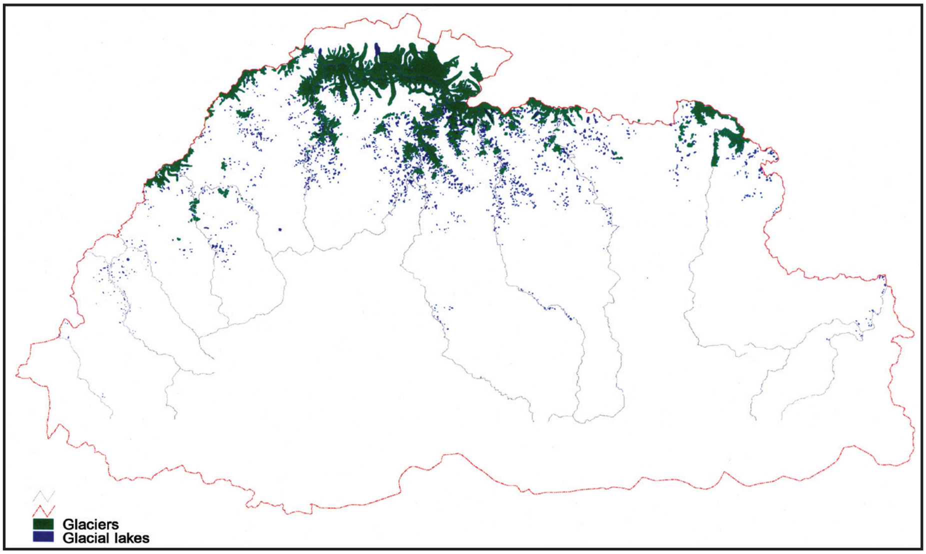

Figure 5: Glaciers and Glacial Lakes in the Bhutan Himalayas

Status of Glacial Lakes in the Puna Tsang Chu River Basin

Numerous studies were conducted on the glacial lakes in Bhutan from 1998 to 2004 during the joint Japan-Bhutan and joint Austria-Bhutan projects in Bhutan. In connection with these studies many scientific articles were published in relation to risk associated with those lakes, mechanism of lake expansion and stability of the lakes, some of which are already cited in the previous sections.

This section gives different scenarios regarding lake expansion both from the earlier works by different experts and results from present work. The discussions are mainly focused on the lakes in two sub-basins namely Pho Chu and Chamkhar Chu sub-basins due to availability of data for comparison and presence of major lakes.

The first detailed work on the expansion of glacial lakes in Bhutan was the work by Professor Yutaka Ageta from Nagoya University Japan with time series sketches of major glacial lakes in

Lunana region in Bhutan Himalayas. In his subsequent study the evolution of a number of lakes was discussed in detail by using maps, photographs and satellite images[2]. Risk of the outburst in relation to the geophysical environment in and around those lakes were also incorporated in his work.

Ageta then examined the rate of retreat on some selected large D-type glaciers associated with large lakes by comparing past photographs, satellite images and maps of different years. Basically applying the concept of lake expansion rate up valley with the corresponding retreat rate for the related glaciers, the authors reported retreat rate in the range of 30 to 35m/year. However the rates were found to be variable with time which was mainly attributed to irregular calving process at the tongue of the mother glacier which is in contact with the lake water.

Luggye Lake

Figure 6 shows the evolution of Luggye Lake from the late 1950s to 1994 and it measured 142m in depth in 2000. The reduction in the surface area in 1994 was due to GLOFs in October 1994. The only risk associated with GLOFs from Luggye Lake in the future could be due to the outlet being blocked by landslides from the left lateral moraine at the outlet causing a rise in the water level of the lake. If ever such a GLOF occurs in future, this will have a serious impact on the Thorthormi Lakes further downstream considering the already weakened left lateral moraine of the Thorthormi glacier.

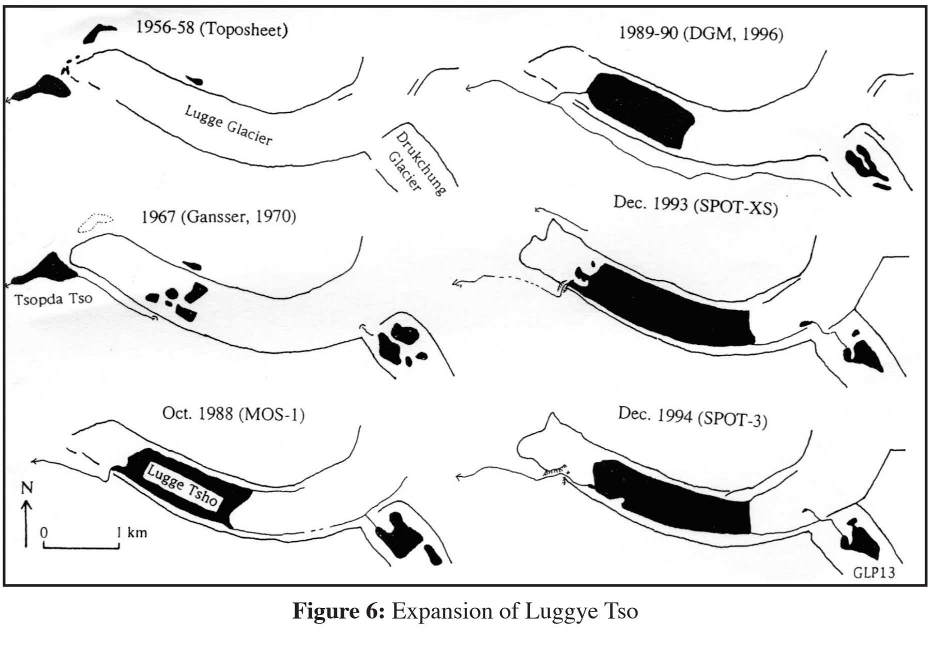

Figure 6: Expansion of Luggye Tso

Similar comment on the risk from Luggye Tso has been reported by the Austrian experts. In fact there were five possibilities proposed during the risk assessment of the Luggye GLOF, as to which outlet being blocked by landslides from left lateral moraine was considered as 'major risk'. Therefore, their recommendation was to stabilize the active sliding zone on the left lateral moraine at the Luggye outlet to allow free flow of water from the lake.

2 The following lakes were studied: Luggye glacial lake, Raphstreng glacial lake, Thorthormi supra-glacial lakes, Tarina lakes and Chubda Tso.

On the contrary, Yeshi Dorji from the Geological Survey of Bhutan observed no immediate GLOF risk from this lake considering the wide outlet channel. He commented that 'the risk of flood from this lake is not there right at the moment as the outlet channel is wide enough to allow any amount of water that will accumulate'.

Raphstreng Lake

Figure 7 shows the expansion of Raphstreng Lake from the late 1950s to 1994 and it measured about 100m in depth in 1999. The present dimension of the lake is believed to be at the end of its expansion since the upstream part has already reached the bedrock wall. Though three phases of mitigation work were carried out on this lake from 1996 to 1998 lowering the lake water level by about 4m, the risk of GLOF still cannot be ruled out considering the large volume of water still stored in the lake and chain effect of GLOF from other adjacent lakes. The building up of hydrostatic pressure in the adjacent Thorthormi lakes, which only have moraine walls as a barrier between them poses a threat to the stability of the Raphstreng Tso.

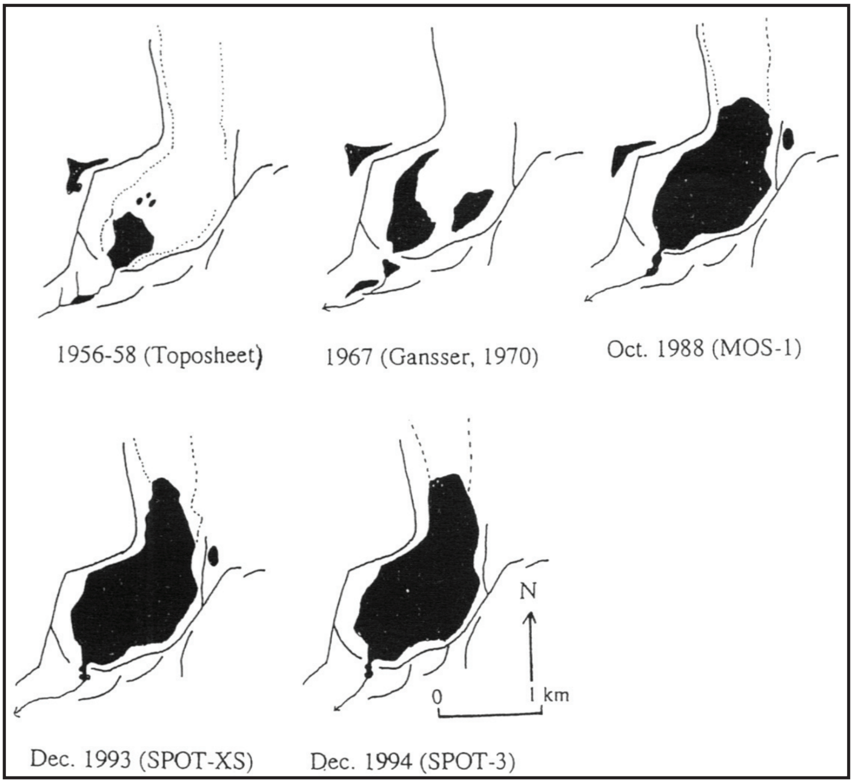

Figure 7: Expansion of Raphstreng Tso

Thorthormi Lakes

Figure 8 shows a time series expansion of the Thorthormi Lakes from 1956/58 to 1993. Ageta reported supra-glacial lakes on this huge debris covered glacier in the 1990s. A continuing expansion of these supra-glacial lakes was seen in 1998 during the first joint Japan-Bhutan field expedition. Considering the accelerated ice melt, gentle gradient at the snout region, eroding of the left lateral moraine ridge by discharge water from Luggye Lake in the upstream and seepage from the left lateral moraine, it was concluded that this growing lake has the potential for outburst in the near future.

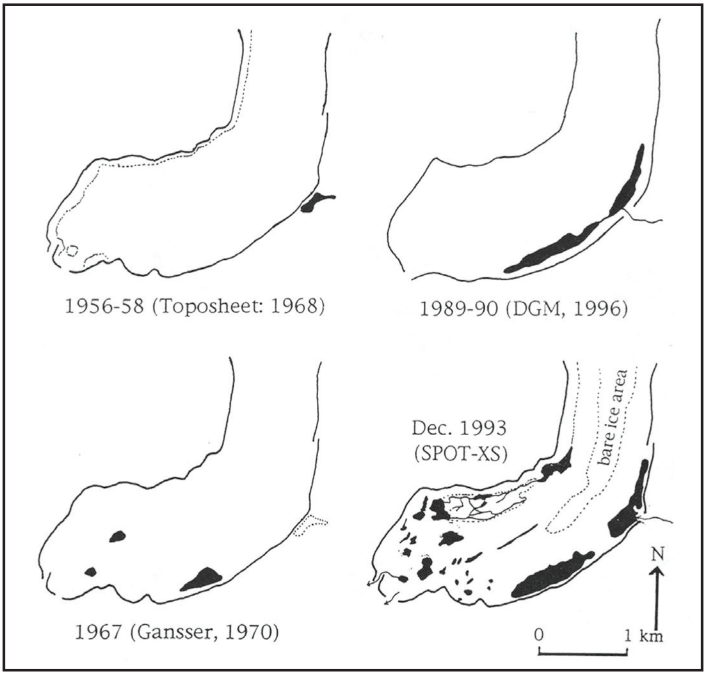

Figure 8: Expansion of Thorthormi Tso

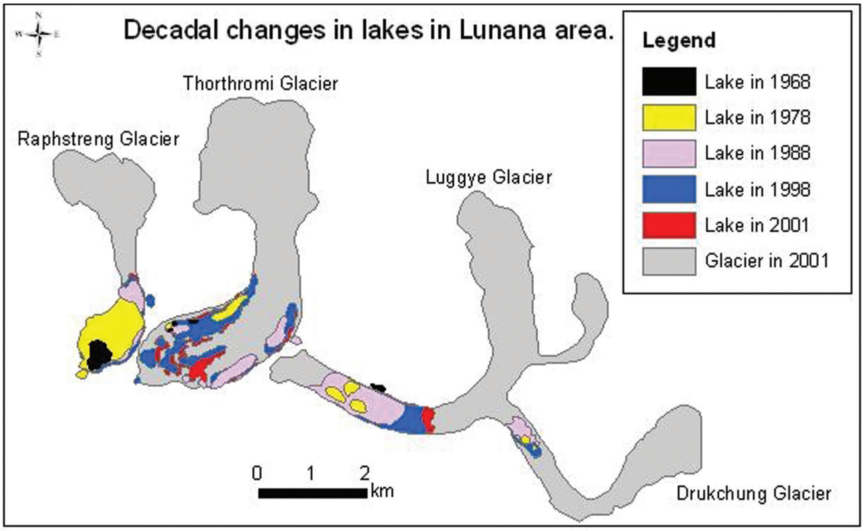

Figure 9: Decadal changes of lakes in the Lunana complex.

An attempt has been made to map the changes of the glacial lakes in the Lunana area on a decadal base from 1968 to 2001 in terms of both area and length (figure 9).

All the three major lakes (Raphstreng, Thorthormi and Luggye) show a sudden increase in surface area and it is clear that all the lakes except for Raphstreng are still expanding and show an expansion pattern.

Potentially Dangerous Lakes in the Puna Tsang Chu River Basin

24 potentially dangerous lakes were identified during the last inventory work based on a set of criteria such as rise of lake water level, associated mother glacier, condition of dams and topographical features of surroundings. The base maps used for their identification were topographical maps from the 1960s. The Thorthormi Lakes were not significant then as no water bodies were detected on the mother glacier (Thorthormi glacier). But today as shown in the previous section the Thorthormi Lakes are considered to be some of the critically dangerous lakes in the Bhutan Himalayas considering their expansion rate and the unstable moraine dam surrounding it. Therefore, the total number of potentially dangerous lakes in the Bhutan Himalayas at present is 25 with the inclusion of the Thorthormi Lakes.

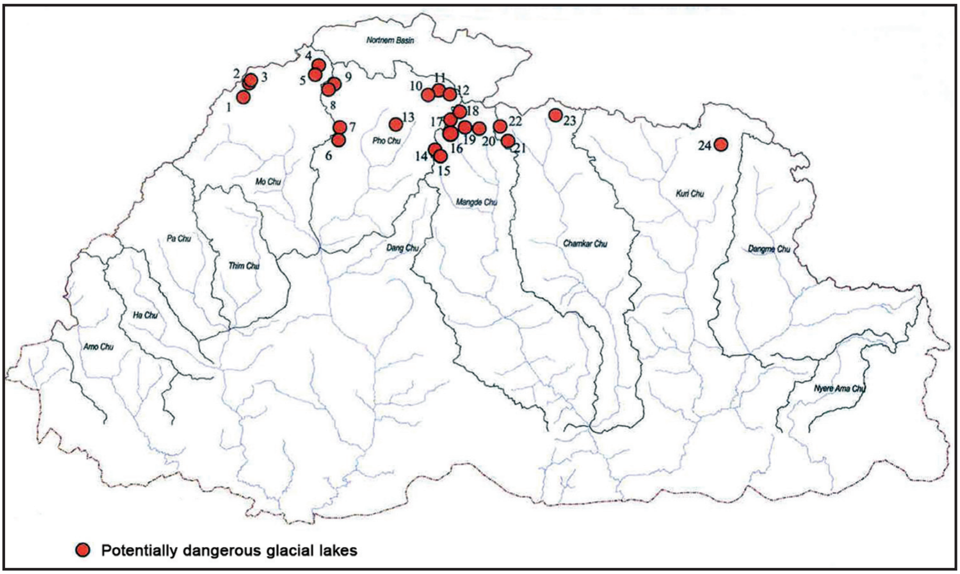

Figure 10: Location of potentially dangerous glacial lakes in the Bhutan Himalayas

The above figure (figure 10) shows the location of potentially dangerous lakes in the Bhutan Himalayas. Out of 25 potentially dangerous lakes, 5 lakes were found at the source of the Mo Chu and 9 lakes were located at the source of the Pho Chu. Therefore a total of 14 potentially dangerous lakes were identified in the Puna Tsang Chu River basin which accounts for 56% of the total potentially dangerous lakes.

Hazard Zones

A hazard is a phenomenon that may adversely affect human life, property, activity or the environment to the extent of causing a disaster. In our context GLOFs from the combination of two potentially dangerous glacial lakes at the source of the Pho Chu are the hazard and we have tried to zone the areas along the Puna Tsang Chu into different levels of hazard from GLOFs. The three hazard zones (red, yellow and blue) identified in this project represent three different hazard levels as outlined below in the table. The technical details and steps involved in the delineation of these different hazard zones are given in the methodology section.

Most of the areas both inhabited and uninhabited along the Puna Tsang Chu from Khuruthang in Punakha to Lhamoizingkha on the Bhutan-India border under Dagana *Dzongkhag* have been covered by this project.

Table 1: Different Levels of Hazard

Hazard Level	Map Color	Descriptions
High	Red	Persons are in danger both inside and outside their houses. Structures are in danger of being destroyed.
Medium	Yellow	Persons are in danger outside their houses. Buildings may suffer damage and possible destruction depending on construction characteristics.
Low	Blue	Danger to persons is low or non-existent. Buildings may suffer little damages.

Red Zone (Prohibited Zone): Represents the area that would be under water in case of worst case scenario GLOF occurrence. All structures in this area would be affected by flood.

Yellow Zone (Regulation Zone): Represents the areas that would be impacted indirectly by the worst case scenario GLOF. Therefore, the existing structures need to be reinforced and future development should be planned accordingly.

Blue Zone (Regulation Zone): Represents the areas that are safe from the worst case scenario GLOF.

Vulnerability Assessments

Vulnerability can be defined as a condition resulting from physical, social, economic and environmental factors or processes which increase the susceptibility of a community to the impacts of a hazard. The IPCC defines vulnerability in relation to the impacts of climate change and it 'is the extent to which a natural or social system is susceptible to sustaining damage from climate change'. In our context it is the degree of risk of GLOF along the Puna Tsang Chu on the lives, property and infrastructure located on either side of this river.

Vulnerability assessment is a way of establishing who is vulnerable, where they are and what the strategies to combat vulnerability are. It is significant for current and future planning exercises for proper risk management, preparedness and critical decision making which are all essential if the most vulnerable people are to be given the assistance they need.

Accordingly, under this section we have tried to compile the details of different sectors which are likely to be impacted based on worst case scenario GLOF in the future. To be more specific and informative we have concentrated more on the areas which have infrastructure and settlements for which the details are given below.

Conclusion

Table 2: Summary of vulnerability assessment in the project area

Hazard Level	Map Color	No. of Buildings	No. of People	No. of Livestock	Historical Monuments	No. of Bridges	Road Length (Km)
Low	Red	117	362	28	16	01	5.22
Medium	Yellow	173	836	220	06	06	8.64
Low	Blue	669	1781	1072	04	00	39.92

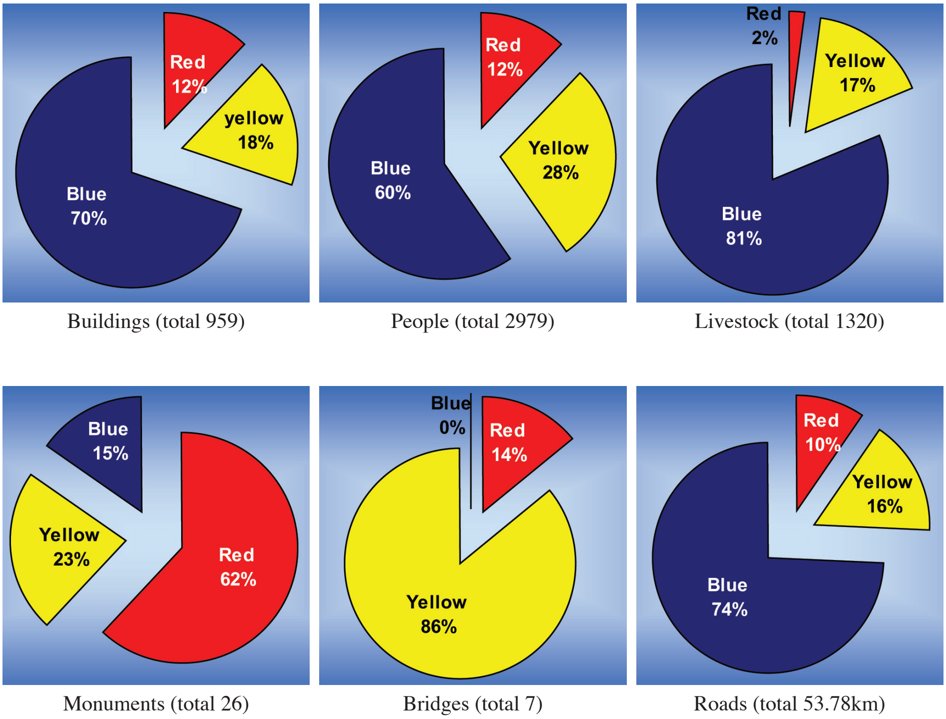

Figure 11: Percentage of socio-economic assets and infrastructure in different levels of hazard for the whole project area.

Table 2 shows the summary of vulnerability assessment in the whole project area.

Figure 11 shows the percentage distribution of different socio-economic assets and infrastructure, which falls in different level of hazards if GLOF occurs along the Puna Tsang Chu. The details of individual vulnerable communities and infrastructure are given in the diagram.

Table 3 shows the areas of different land use in different levels of hazard along the Puna Tsang Chu.

Table 3: Different land use in different hazard levels in the project area.

Hazard Level	Map Color	Cultivated Land (Km)	Arid Land (Barren, Open, Scrubs (Km)	Forest Cover (Km)	Built Up Area (Km)	Orchard (Km)	Total (Km)
High	Red	0.411	1.084	2.586	0.106	0.022	4.239
Medium	Yellow	1.330	1.134	2.585	0.193	.136	5.378
Low	Blue	5.882	7.988	26.378	1.797	0.308	42.534

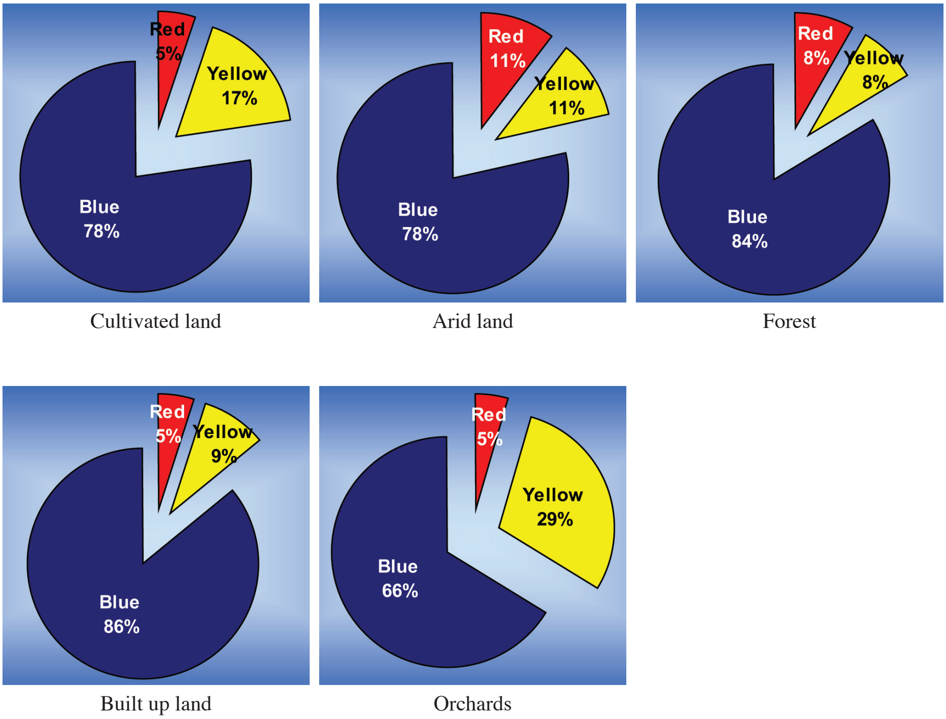

Figure 12: Percentage of different land use in different hazard levels for the project area.

Since any kind of flood will have a devastating effect on the land use type along its course it is imperative to make an assessment on the vulnerability of land use along the Puna Tsang Chu for future GLOF scenarios. Figure 12 shows the percentage of different land use in different hazard levels for the entire area of the project area.

Conclusions and Recommendations

The main output from this project is the hazard and vulnerability maps for GLOFs along the Puna Tsang Chu from Khuruthang to Lhamoizingkha at the Bhutan-India border. These maps can be used for future planning of various developmental activities and as a tool for better decision-making by concerned authorities. This project identified the areas along the Puna Tsang Chu with different level of hazards of GLOF. As a main recommendation for future projects, it is suggested to identify a safe area for each community selected in this project. This sort of study will require a series of data and an entirely different working methodology for delineating a safe zone area for evacuation purpose during the time of GLOF in the future.

Building Adaptive Capacity in Two Vulnerable Semi-arid Mountainous Regions in Bolivia

Javier Gonzales, Marylin Aparicio, Jorge Cusicanqui, William Dougherty, Tahia Devisscher

1. Introduction

Since the Rio Summit in 1992 different actions have been promoted and implemented to improve the capacity of countries to combat and adapt to climate change. Mitigation strategies to reduce greenhouse gas emissions are currently implemented under the Kyoto Protocol framework. Along with mitigation, adaptation to climate change effects is gaining importance in the international agenda due to increasing intensity and frequency of climatic hazards that are impacting natural and socio-economic systems worldwide. Both mitigation and adaptation will be needed to reduce climate change effects while contributing to human development. This challenge is substantial, particularly in developing countries where human development is dependent on the state of the natural systems and is therefore more vulnerable to climate change effects. In developing countries, the achievement of the Millennium Development Goals (MDGs) is currently jeopardized by climatic hazards and this situation will worsen over time if these countries do not build adaptive capacity to prevent and adapt to climate change effects.

Climatic hazards in Bolivia have become an additional challenge to achieving poverty reduction objectives. The costs of the "El Niño" event in 1997/98 represented about 6% of the GDP and the flooding of the Mamore River in 2006/07 exceeded 400 million US$. In urban areas, the effects of climatic events have caused infrastructure loss and in rural areas agricultural activities have been seriously affected, threatening the sustainability of local livelihoods and causing massive migrations to the country's main cities. The negative social indicators and the high poverty incidence in Bolivia, as well as a narrow economy mainly based on agricultural production and primary resource extraction, increase the country's vulnerability to climatic hazards resulting in large impacts on the productive sectors and human development.

Recognizing the importance of building capacity in the country to cope with potential climate change effects, the Bolivian government agreed to cooperate with the government of the Netherlands to implement the Netherlands Climate Change Studies Assistance Program (NCCSAP) in 1998. After successfully completing the first phase of this initiative, Bolivia started the second phase of the NCCSAP (NCAP II) in 2004. Acknowledging that protecting local communities from climate change related risks based on a top-down approach can alienate and in some circumstances negatively affect communities, this second phase adopts a local-level approach to build adaptive capacity in the country. On this basis, the NCAP focuses on assessing the vulnerability and developing adaptive capacity in local communities of two vulnerable semi-arid mountainous regions in Bolivia. The scope of the study includes the vulnerability of local human subsistence systems through assessing the potential impacts caused by climate change effects on food security and human health in the selected study areas. Adaptation strategies are then identified and implemented at the local level contributing to the development of the national adaptation capacity by serving as pilot studies for the design of the National Adaptation Plan (NAP) and the Global Change Strategy of the National Development Plan.

2. Rationale, Objectives and Methods

2.1 Rationale

The mountainous regions provide important ecosystems services, particularly as a source and storage of high quality water that can be used for domestic purposes and agricultural activities. The conservation of these ecosystems is therefore fundamental for the development of socio-economic systems and for the support of life in general.

Because of high quality water resources, the mountainous regions in Bolivia sustain the highest rural population densities in the country. In these regions the level of poverty is high – more than 70% of the local population lives in poverty conditions – and even though poverty reduction measures are being implemented, poverty conditions and vulnerability of these human settlements may be enhanced by climate change. The population settled in these regions depends largely on the ecosystems' services for their productive activities and subsistence based mainly on agriculture. Their production systems are particularly vulnerable due to the low level of technology, insecure land tenure, limited size of land property and poor economic diversification. Hence, climate change effects on ecosystems of mountainous regions can have serious consequences on the local livelihoods in these regions which affect human development conditions. Climate change effects can not only negatively impact their livelihoods (particularly food security), but also provoke an emergence and expansion of vector transmissible diseases such as Malaria and Chagas increasing the pressure on human health in these regions.

The situation described above is particularly sensitive in semi-arid mountainous regions where scarcity of water resources can be exacerbated by climate change. In these regions water availability can decrease up to 50% of the potential resources due to temperature rise and precipitation decrease. According to future climate projections in Bolivia, the inter-Andean xeric valleys will be one of the most vulnerable regions due to its xeric climate and orographic isolation. Other highly vulnerable ecosystems to climate change are the ecotones of the sub-Andean valleys that have periodic rainfall.

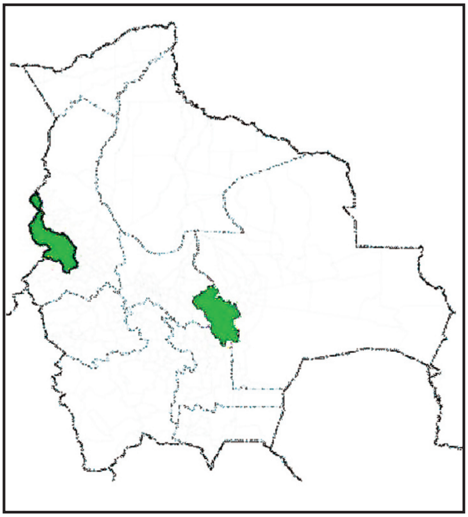

Figure 1. Pilot Regions Selected as Case Studies for the NCAP Project in Bolivia

To evaluate this situation and find possible preventive measures, two vulnerable semi-arid mountainous regions in Bolivia have been selected as the scope of the study: the region of the Lake Titicaca and the region of Vallegrande[1] (see figure 1). These regions were selected as pilot studies based on physiographic criteria, watershed management considerations and political division. The project focuses mainly on human

1 The Titicaca region was selected as a study area because it is highly sensitive to hydrological changes due to glacier withdrawal. Furthermore, it is delimited by the Northern Altiplano Basin which is an international watershed area shared by Peru and Bolivia and is currently regulated by both countries. The Vallegrande region is located in the middle basin of the Grande River and has been selected because it is the upstream watershed area of the Santa Cruz Provinces that have demonstrated interest in reducing the environmental impacts upstream that are causing sedimentation and floods downstream and have given special attention to risk and disaster prevention.

subsistence systems by assessing food security and human health in both regions. Although the focus is placed on those two sectors, water resources play a fundamental role in the assessment, mainly due to the potential direct impacts of climate change on the local hydrology and the effects this may cause on local livelihoods.

2.2 Objectives

The objectives of the project are (see table 1): 1) to improve the understanding of climate change risks, the vulnerability and adaptive capacity of local communities in semi-arid mountainous regions in Bolivia, 2) to develop a cost effective methodology for rapid appraisal and monitoring of climate change vulnerability and 3) to build adaptive capacity in these regions using a participatory approach to identify preventive adaptation measures focusing on food security and human health. The results of the study will complement policies and measures implemented at the local and national levels.

Table 1. NCAP Project Objectives

Objective 1	Assess the local vulnerability and adaptive capacity of the two study areas
Objective 2	Identify suitable adaptation strategies to implement at the local level
Objective 3	Assess current policies and develop preventive adaptation strategies to climate change, focusing on food security and human health

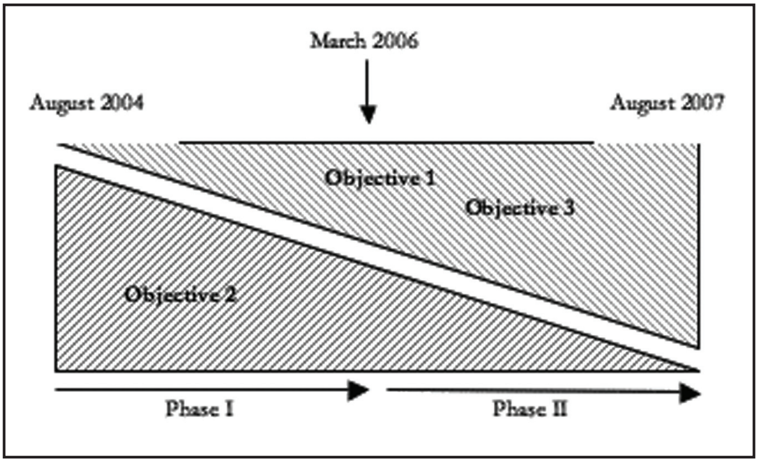

Figure 2. NCAP Project Phase I and Phase II

The project was implemented in two phases (see figure 2). Phase I involves a vulnerability assessment of climate change effects mainly evaluating food security and human health vulnerability. This phase included diverse studies: a climatology evaluation; a diagnosis of the ecosystem; an analysis of the production and socio-economic systems; an assessment of possible bio-indicators for climate change; a retrospective assessment of the Malaria outbreak in the Lake Titicaca region; an analysis of the traditional knowledge to estimate local climatic conditions; and the identification of potential adaptation measures for each study area. Parallel to the local-scale evaluation, a national-scale assessment was conducted in phase I to determine the potential impacts of climate change on the different sectors in the country. Phase II focuses on completing the vulnerability assessment and evaluating the identified options to develop strategies for adaptation to climate change – with particular focus on local livelihoods (food security) and human health. This is to be incorporated into the development plans of each study region and implemented by the local governments and communities, and considered as pilot studies in the development of the National Adaptation Plan and the Global Change Strategy under the National Development Plan[2].

2.3 Methodology

The NCAP-Bolivia followed the principles suggested in UNDP/GEF Adaptation Policy Framework:

- Adaptation to short-term climate variability and extreme events were used as a basis for reducing vulnerability to longer-term climate change
- Adaptation policy and measures were assessed in a developmental context
- Adaptation occurs at different levels in society, including the local level
- The adaptation strategy and the process by which it is implemented are equally important

As previously mentioned, the study focuses on: 1) two semi-arid mountainous regions: the region of the Lake Titicaca and the region of Vallegrande; and 2) two sectors to assess the vulnerability of human subsistence systems to climate change: food security and human health. Under this framework, water resources are assessed as a cross cutting issue.

The project has adopted both a participatory and an integrated approach. The vulnerability assessment and the identification and design of possible adaptation measures have included the active participation of local stakeholders in the process through consultation, questionnaires, interviews, workshops and focus groups. In the region of the Lake Titicaca, 12 communities were selected to carry out the participative assessment, 6 communities were involved in the assessment of the productive systems (food security) and 6 communities were involved in the evaluation of the local public health system (human health). In the Vallegrande region the participative assessment was carried out with 14 communities. The participative approach is important 1) to validate and triangulate information obtained during the assessment, 2) to gain a better and more objective understanding of the local reality and needs, 3) to understand the local perceptions of climate change effects, and 4) to identify local knowledge that can be used to build adaptive capacity at the local and national levels. The stakeholders involved in the process were local authorities, farming organizations and independent farmers, local institutes, and staff working in health centers located in the study regions.

In addition, the integrated vulnerability assessment of both regions encompasses different disciplines to evaluate ecosystem vulnerability, the hydrologic system, climatic variability, productive systems, traditional knowledge and current policies influencing production systems and human health. An integrated approach is also used for the development of adaptation strategies. Different tools and methods are used for the integrated assessment: GIS tools for multi-criteria analysis; participatory tools for evaluation and planning; questionnaires, rapid appraisal methods and web-based tools to exchange information and promote communication on climate change related risks.

Finally, the project complements the top-down planning process with a bottom-up process of capacity building. While the study contributes towards developing national adaptation policies and strategies working with national authorities and departmental centers of the health system, the participatory approach used to build adaptive capacity in the two selected regions allows designing and implementing adaptation measures from the bottom-up that can serve as case studies in the

2 The Global Change Strategy puts emphasis on enhancing adaptive capacity in strategic sectors of the country.

development of national policies. The project also explores creating synergies with current policies and measures implemented at the local and national levels in the context of rural development, watershed management, public health and education.

The following sections present the key results obtained in the different studies carried out for phase I, as well as the local perceptions of climate change effects and the associated risks for local production systems and human health. The key results for the Lake Titicaca region are described first, followed by the Vallegrande region. The next section presents the adaptation strategies developed for each study region and some activities carried out to build adaptive capacity in different municipalities. The last section summarizes the lessons learned and gives strategic recommendations.

3. Key Results and Findings

3.1 Description of the Lake Titicaca Region

This study region is located in the dry inter-Andean valleys of Bolivia and covers the municipalities of Batallas, Ancoraimes and Carabuco. These municipalities are located in the northern area of the Bolivian Altiplano. The northern Bolivian Altiplano is an 800km long and 200km wide flat region in the Andean highlands and is highly sensitive to hydrologic changes caused by glacier withdrawal. In general terms, the North Altiplano Basin is divided into 3 altitudinal ecological zones: the region of the Andean mountain range (4,300 to 6,500m above sea level), the foot of the hill (4,300 to 4,000m above sea level) and the flat land (3,850 to 4,000m above sea level). Almost 75% of the North Altiplano Basin is between 3,600 and 4,300m above sea level.

Although the climatic conditions in this region are not favorable for the production of many crops, 65% of the economically active population is dedicated to agriculture. Potatoes and quinoa are the main crops produced under dry conditions in this region. Drought and low temperatures combined with low soil fertility and a lack of access to external productive factors to intensify the production have resulted in very low productivity levels in the Lake Titicaca region.

3.1.1 Climate in the Lake Titicaca Region

The climate of this region is influenced by its altitude. Given the altitude and the geographic location, this region faces significant climatic variations: it receives high sun radiation during the day (reaching 533cal/cm^2/day) and it has low temperatures during the night. The maximum average temperature in the northern Altiplano ranges from 15 to 17 °C during the day and a minimum average temperature of 0.5 °C in summer and -10 °C in winter during the night. The average temperature in the region varies between 7 and 8 °C. Moreover, the average velocity of wind in the region is 3m/s with a predominant direction coming from west-southwest.

The climatic conditions of the region are also determined by low levels of humidity. Average precipitation in the Altiplano is 550mm/year. Almost 72% of the rainfall occurs from November to February. The cold weather, high daily temperature variation and low humidity levels of the highlands limit the growth rate and density of vegetation in this region, resulting in low levels of organic matter in the soil and consequently in poor soil fertility.

Moreover, Lake Titicaca has a thermo-regulator effect on the region. The level of humidity in the area surrounding the lake is higher due to the evaporation process of the water reaching an average precipitation of 600mm/year that favors the climatic conditions of the area it influences.

Finally, the region of the Lake Titicaca is greatly influenced by the “South Oscillation El Niño” (ENSO) also known as the “El Niño” that causes serious droughts in the area. This event does not have a fixed cycle and is currently being researched, however it is estimated that its frequency of occurrence is around 4 years. The "El Niño" event is part of the rainfall pattern of the northern Bolivian Altiplano.

3.1.2 Ecosystem Diagnosis

The objective of the ecosystem diagnosis is to assess the state of conservation of the ecosystem in the study region and to identify (using bio-indicators) changes in the ecosystem due to climate change and subsequently assess the potential implications on food security and human health. The area selected for the ecosystem diagnosis in the Lake Titicaca region is the Caldera zone in the municipality of Ambana, the municipality of Combaya and the municipality of Batallas. The study of the fauna and flora in this area was carried out in coordination with the Bolivian Collection of Fauna (CBF) and the National Herbarium of Bolivia in La Paz. The most relevant findings of the study are described in this section.

Changes in the State of Conservation of the Ecosystem and the Implications for Human Health and Food Security

The flora in the study area is mainly threatened by the expansion of agriculture and cattle production. The areas covered by native vegetation are few and are generally located in areas with difficult access along water streams and in fragmented forest patches, as well as in rocky ravines that are not suitable for crop production. The areas with easy access are generally covered with introduced crop species and also opportunistic species with low requirements for water and nutrients. These species compete with native species that have the potential to provide higher value as forage and which are more important for the conservation of the ecosystem.

One of the main threats to the fauna in the study area is the introduction of invasive species such as the *Mus musculus* (domestic mouse). The relative abundance of this species in the zone of Caldera is surprisingly higher to that of any native species. Several studies have shown that the presence of this species can cause an emergence of tropical diseases due to its constant contact with vectors. Therefore, it is important to monitor the population of *Mus musculus* in the area, because it is a potential threat to both human health and food security.

The main pressure placed on bird populations is the destruction or modification of their habitat. The depositing of sediments and drainage are affecting the Andean wetlands and rivers, as are the mining activities and the disposal of heavy metals. The forest relicts are threatened by wood extraction for fuel affecting the birds that live in these ecosystems and the birds that live in the Lake Titicaca are endangered by the nets that local fishermen use to catch fish in this habitat.

Finally, although in general terms the entomofauna is affected by the fragmentation of forests and the over-exploitation of natural resources in the study area, some species of insects may be favored if climatic extremes have greater intensity and frequency in the area. The presence of *Anopheles pseudopunctipennis* (vector of Malaria disease) in the area – a vector that is not typical for areas higher than 2600m above sea level – already represents a threat for human health in the community of Caldera and its surroundings. This threat can become even more severe if temperature and rain intensity increase causing the migration of more vector species from lower strata to the study area. The species *Triatoma sp.* (vector of Chagas disease) has not been identified in the study area. Among the insect species that could be favored by climatic variability and could represent a threat to food security are *Acromyrmex spp.*, *Phthorimaea operculella*, *Aphis gossypii*, and *Premnotrypes spp.*, all plagues that can affect the quality and availability of the main crops produced in this region.

Potential Bio-Indicators for Climate Change

Flora species that have been suggested as bio-indicators for climate change in this region are: dominant species of forest relicts such as *Schinus andinus*, *Polylepis racemosa*, *Myrsine pubescens*; less dominant species such as *Escallonia myrtilloides*, *E. paniculata*, *E. resinosa*, *Mutisia lanata*, *Duranta spp.* and some climbing species such as *Fuchsia apetala* and *Passiflora inca*.

Other species that have been identified as potential bio-indicators for climate change are good indicators of humidity and depend on water for at least one stage of their life cycle. Species with these characteristics in the region are bryophytes such as *Radula voluta*, *Porella sp*., *Leptodontium longicaule*, and *Thuidium sp*. Other important bio-indicators of climatic variability are ferns, in particular epiphyte ferns of the families Gramitidaceae and Hymenophylaceae.

Fauna species that could be potential bio-indicators for climate change are small mammals that play an important role due to their ecological functions within ecosystems and their sensitivity to temperature changes, availability of natural resources and the quality of ecosystems in general. The study has identified species of chiroptera that belong to the Vespertilionidae and Molossidae families in the study area although these are typical of lower ecological strata. The altitudinal migration and presence of these species in the study area suggest that monitoring their population over a longer time period may be a good way of identifying and evaluating climate change. Also, species of rodents of the *Phyllotis* genus that are typical of inter-Andean valleys can be good bio-indicators for climate change, as well as species of the *Akodon* and *Oligoryzomys* genus that are typical species of lower ecological strata.

There are a total of 21 bird species with migration patterns (austral, altitudinal or other type) that have been identified in the study area. Given that their migration is related to climatic conditions, it is suggested that monitoring the population of these species will help to assess climate change. Bird species that are present outside their altitudinal range or life zone can be particularly important in evaluating climate changes. In the area of Caldera, a total of 30 bird species were identified. Although the majority of these species were typical of the area, 5 species were over their altitudinal range. For sedentary species, population behavior during their reproduction stage or their nesting stage can be assessed to evaluate climatic variations.

Lastly, to identify and validate the bio-indicators for climate change proposed in this section, a monitoring system needs to be implemented. This system should include the modeling of ecological niches encompassing the relationship between abundance and distribution of populations. Rare species and species with limited distribution should be given a higher status.

3.2 Livelihoods Vulnerability and Risk Perceptions in the Lake Titicaca Region

3.2.1 Production Systems Vulnerability

Production systems play a fundamental role in the human subsistence in the Lake Titicaca region. In general, the production systems in this region are for personal consumption. These systems are generally precarious and therefore highly vulnerable to climate change effects. To prevent the potential impacts of climate change effects on food security and increase the resilience of these subsistence production systems by implementing suitable adaptation measures, an assessment of climatic hazards on the local production systems was conducted.

This section first presents the results obtained in the agro-climatology assessment. This information is useful in determining the most suitable production and risk prevention strategies in the area. Secondly, the main findings of the agricultural systems assessment are described. Thirdly, the local perceptions of climate change and the effects on the production systems are presented, as well as suggestions for possible adaptation measures that were identified with the local stakeholders. Finally, a short description of the state and vulnerability of the water resources in the region and the associated implications for the production systems is given.

Agro-climatology Assessment

The temperature in the Lake Titicaca region follows a typical tendency for a tropical region located at high altitude: while the thermal difference during the day is high, the annual range is short. During a year, the period that presents the lowest temperature variation/difference (10 to 14ºC as opposed to 15 to 19ºC) is between October and April. Within this time range, there is a period of 160 days (November to March) that is considered to be free of frost occurrence (< 50% of probability/day). This period that is frost free, coincides with the occurrence of rain fall in the region. As a result, the agricultural activities are concentrated mainly between the months of October and April and the selection of crops is reduced to those that have a short productive cycle and good adaptive capacity to daily temperature variations of 10 to 15 ºC.

In the northern Bolivian Altiplano, the agriculture systems face two main climatic hazards: droughts and frosts. The geographical location and altitude of this region result in a period with a high risk of frost occurrence between April and mid-October. The rain variability in the arid regions is very high and therefore a drought period is difficult to determine in these regions. However, by assessing the distribution of very dry, dry, normal, and wet years, it is possible to estimate that the risk of years with drought occurrence is high (40%), where 3 out of 10 years the occurrence of drought is considered to be normal. Moreover, a period of 160 days with a high rainfall has been identified between the end of October and the end of March, with 70% of the annual precipitation falling between December and March as well as a high correlation between the start date and the length of the rainy season. If the rainy season starts at an early date it lasts longer. For instance, if the rainy season starts the third week of October, it lasts for about 6 months. However, if the rainy season starts in mid December, it only lasts for 3 months. This means that a late start of the rainy season will cause a water deficit, reducing the productivity of crops that need at least 5 months to develop. This in turn will negatively impact the production systems and therefore food security in the region.

In addition, the Lake Titicaca region faces two short dry periods within the rainy season, generally one at the beginning or at the end of the rainy season and another during the rainiest months (December to March). Under these conditions, it is very probable for the crops that have been introduced in October to face a dry period of two weeks in February. Considering that at this time of the year these crops are generally flowering or developing grains, a drop in productivity due to a shortage of water can be expected. This situation is aggravated when the short dry periods during the rainy season last longer. These droughts disturb the agricultural production planning in the region, delay the sowing and/or make it necessary to repeat the sowing due to failure in the first round.

Finally, the aridity index in the Lake Titicaca region classifies it as a semi-arid region because only 34% of the atmospheric water demand is covered by precipitation[13]. During the rainy season this index increases to 65%, reducing the stress on the crops cultivated in the region. Figure 3 shows that the monthly surplus precipitation calculated for 25%, 50% and 75% probability is lower than the level of evapotranspiration. However in the month of January the precipitation calculated at 25% probability exceeds the absolute evapotranspiration. This means that the water deficit in the area over the year is severe and consequently agriculture without irrigation is considered under constant stress, even during the rainy season.

To conclude, it is possible to state that the production systems in the Lake Titicaca region face significant climatic hazards that determine their successful development and consequently the food security in the area. The probability and frequency of frosts and droughts is high and they would jeopardize the production systems in the region. This is aggravated by high rainfall variability. In particular, when the start of the rainy season is delayed, crop production can be seriously affected due to water shortage. The low temperatures and water availability in the region over the year slow down the physiological activity of plants extending their productive cycle and making them even more vulnerable to the effects of frosts and droughts, in particular during the last stage of the

3 Aridity index calculated using the UNESCO methodology.

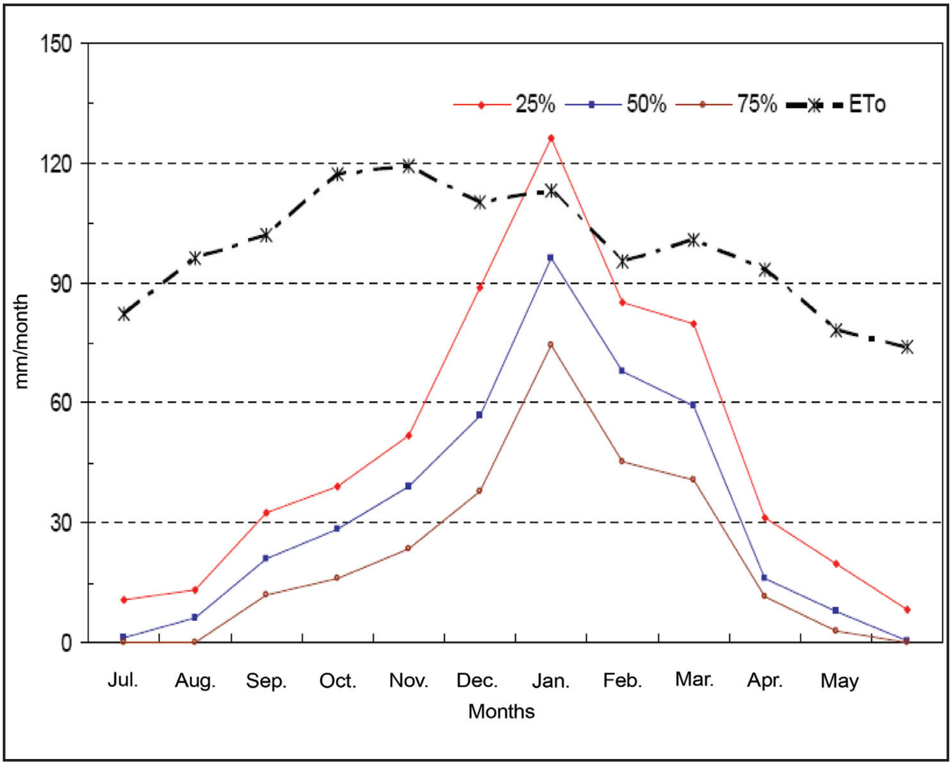

Figure 3. Monthly Levels of Rainfall at Different Probabilities of Evapotranspiration

rainy season. As a result, it is very important to select crops that are resistant to climatic variability and have short productive cycles. It is also necessary to consider that the implementation of an irrigation system, at least during the critical stages of the crops' development, could significantly increase the productivity and adaptive capacity of the production systems in the region, contributing to food security and the sustainability of livelihoods.

Production Systems Assessment

The agricultural production in the Lake Titicaca region is mainly for personal consumption due to the limited land property size and the low means that each family has to produce in this area. About 34% of the local population has stated that the potato is the main crop produced in the study area, followed by quinoa (25%) and broad bean (23%). Besides the important role these crops play for food security, these crops also have significant value for the local economy due to their profitability and high demand in the local, national and international markets. In addition, other crops are cultivated in the region such as cereals (tarwi and cañahua), vegetables (peas), and tubers (oca and papaliza).

In general, the production area per family in the region is smaller compared to two decades ago. The decrease in the size of land property for agricultural use is due to the distribution of inherited land from generation to generation within a family. As a result, current farmers have a small area of land property (sometimes no larger than a furrow) because over time the family plot has been shared out among all the family descendants. This limits the amount and diversity of crops that a family can produce in this region.

In addition to crop production, the local communities in the region, in particular those located on the flat land, diversify their production with cattle breeding. Dairy production is important for these communities and the families that have cattle use their agricultural land to produce forage for the livestock, such as oats and alfalfa. Dairy production is generally complemented with the breeding of sheep and pigs for personal consumption. Another important production activity for the communities located near the lake is fishing. The fish that are caught in the Lake Titicaca are mainly for commerce, contributing to the economic resources of the families in this area.

In summary, the production systems in the Lake Titicaca region are mainly based on the production of crops such as potatoes, quinoa and broad bean and cattle breeding mainly for dairy production. Fisheries are an additional economic activity for the communities located near the lake. Generally, production in the region is not only for commerce but also for personal consumption, which is important for local food security. Unfortunately, the poor conditions in the region and the limited size of available land for agricultural use shape the productivity and vulnerability of the production systems affecting their capacity to cope with climatic hazards such as droughts and frosts. In this sense, an increase in intensity and frequency of climatic extremes places the food security and the socio-economic system of the local population at risk.

Local Perceptions: Climate Change Effects on the Production Systems and Possible Adaptation Measures

Local perceptions of climate change were collected through questionnaires and workshops. Among the local population that answered the questionnaires[4], more than half viewed drought to be the most important climatic hazard affecting production systems, followed by frost and hail. Around 77% of the people interviewed stated that droughts have become more frequent and have increased in intensity, 76% pointed out that frosts occur more frequently, 66% affirmed that frosts now occur "out of season" and have become unpredictable, 74% believed that the temperature in the region has increased over time, and 88% stated that precipitation has decreased and is now concentrated within a few months of more intense rain instead of a more uniform distribution throughout the rainy season.

Table 2 summarizes local perceptions of climate change and the effects on production systems and food security collected during workshops with local stakeholders including local authorities and leaders, farmers, and community members. It also presents proposed adaptation measures. Box 1 presents the traditional knowledge system used to estimate/predict the annual climatic conditions and subsequent planning of agricultural activities. It is suggested that traditional knowledge can complement the current systems used to evaluate weather and climatic variations and can contribute towards developing adaptive capacity in the region.

During the workshops local stakeholders recognized the necessity to prioritize strategic agricultural fields that have better adaptive capacity to climate change effects. Based on a multi-criteria analysis that considers several factors such as productivity, nutrition level, prices, hand labor and fertilizers requirement, soil requirement and potential risks, the following production fields were prioritized for the flat areas: alfalfa, oats, pastures and barley. For the areas located at the foot of the hills the prioritized production fields were: quinoa, alfalfa, cattle, dairy production and barley

Water Resources Vulnerability

Rain water resources are limited in the northern Bolivian Altiplano. Only a few communities have irrigation systems, particularly in the higher areas. Among the communities that have permanent access to water, only a few implement an improved irrigation system. However, these systems are deteriorating due to lack of maintenance. The main rivers in the region contain water for the majority of the year and are used by the communities for irrigation. There are two main sources

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4 A total number of 90 questionnaires were carried out per municipality, equivalent to 180 questionnaires for the study region.

Box 1. Case Study: Traditional knowledge that can be used for Climate Change Adaptation

Traditional knowledge based on the observation of nature to predict weather and take decisions on crop production is widespread in the country and its systematization has begun to attract the interest of scientists and society. The objective of this case study is not only to understand the mechanisms of traditional systems to assess climatic conditions, but also to evaluate the relevance of these systems from a vulnerability and climate change adaptation point of view.

Traditional systems that assess climatic conditions are based mainly on systematic observation of indicators and analysis. For this reason, it is possible to state that this type of knowledge is compatible with the current scientific knowledge. Farmers take important decisions about their production at critical points of the year based on the analysis of observations, and use festivities as reference points in the solar calendar (currently the Gregorian calendar). Observations of indicators and analysis allow for understanding and "predicting" the climate characteristics in the productive year and how to plan production activities to obtain a good harvest.

Specific plants are used as indicators to prepare and carry out agricultural activities. Animals and animal behavior are also used as indicators to predict whether a year will have droughts or a long rainy season. In past years, local farmers in the region have noticed a change in the climate and affirm that it has become more unpredictable and complex to predict.

Traditional knowledge is becoming lost as a result of migration to the cities by younger generations, secularization, and the introduction of technology and modernization into the region. However, recent interest in traditional knowledge is attempting to re-value this system recognizing it as an integrated analysis system complementary to the weather and climate assessment methodologies currently used.

of water in the Lake Titicaca region: glaciers and rain. In past years, glaciers in the region have been melting and problems associated with a lack of available water resources have become more severe. This situation is expected to worsen in coming years due to climate change.

The coverage of drinking water services in the communities in the study area is deficient. Only 35% of communities have easy access to drinking water services. A potable water system is under construction for 12% of the communities and the remaining 53% of the population does not have access to drinking water. The quality of the system is deficient, some communities need an extension of the system and several communities need an improvement in infrastructure. Also, some communities do not have sanitary systems with the exception of some households and educational centers.

In several areas surrounding the Lake Titicaca, drinking water is obtained from both rivers and groundwater wells built with stones or cement. About 40% of drinking water in the region comes from these wells. Water in these wells is generally extracted with water pumps or manually. In general, water from rivers and wells is not boiled before being consumed resulting in parasitic infections.

With regards to local perceptions, more than half of the people interviewed (79%) believed that 10 years ago water for irrigation was sufficient; however 76% believed that current water resources are scarce in the region and are not sufficient for human and cattle consumption or for crop irrigation. Table 3 summarizes local perceptions of the risks affecting water resources in the region and the associated effects on production systems, as well as some suggested preventive measures.

Table 2. Local Perceptions of Climate Change and the Associated Effects on the Production Systems and Food Security, and Suggested Adaptation Measures

Local Perceptions	Adaptation Measures
The rainfall season has changed; rain is starting later delaying the sowing. Because the rainy season is shorter, the suitable period for production has also shortened. Due to water scarcity and drought some crops such as broad beans cannot be cultivated.	New resistant crops have to be developed for the area.
Frosts are "out of season" and have become unpredictable affecting crops such as potatoes.	New varieties of potatoes that are resistant to frosts need to be introduced into the region.
Frosts and hail have increased in intensity sometimes causing the loss of entire production fields.	Crops have to be cultivated again in the hills. Community fires have to be organized to prevent the impacts of frosts.
Droughts are more intense and frequent than previous years and the soil dries faster.	Suitable irrigation systems and crop varieties that are resistant to drought should be introduced.
Higher temperature and rain intensity (within a few months) increase the risk of plagues. Plagues have become more aggressive affecting crops, in particular potato production.	
Lower productivity does not allow for surplus production to be commercialized, affecting the monetary income for local families.	
Crops used for personal consumption have been replaced by commercial crops.	Re-introduce crops that were used for personal consumption to ensure food security.
Higher rain intensity (within a few months) affects the pastures and crops cultivated on the flat areas.	Drainage systems have to be developed.
Temperature rise is affecting the cattle, increasing their susceptibility to diseases.	Introduce new cattle that are tolerant to temperature variability and improve control of animal diseases. Introduce new forage varieties resistant to drought.

Table 3. Local Perceptions of Risks Affecting Water Resources and Suggested Adaptation Measures

Local Perceptions	Adaptation Measures
Rainfall is more concentrated within a few months, particularly in February.	It is important to find new water sources.
Water resource scarcity is affecting the production of crops such as potatoes and barley and forage such as alfalfa and pasture.	More wells are needed and more water pumps need to be installed. Productivity needs to be improved with the introduction of improved crop varieties and animal breeds, as well as improved technology.
Conflicts over water resources between communities have increased.	It is necessary to improve the irrigation systems and their maintenance.
Rivers are starting to dry and do not always contain water throughout the year affecting human and animal consumption and also the production systems in the area.	
Irrigation systems are not properly maintained, current infrastructure is deficient and the administration of irrigation systems lacks capacity.	The administration capacity needs to be strengthened and the construction of more reservoirs and irrigation channels is necessary.
There is a lack of knowledge about the importance of vegetation for water storage and the proper use of irrigation systems.	
The contamination of the Lake Titicaca is affecting the fisheries.	Organizational capacity of the fishing communities needs to be strengthened.

3.2.2 Human Health Vulnerability

The correlation between health and climate is highly complex due to the multi-causal origin of the former and the multi-systemic influence of the latter as a determining factor. Moreover, impacts on human health caused by climate change effects greatly depend on the socio-economic development and organizational capacity of a community and the state of the natural system in the area. In this sense, human health vulnerability to climate change effects of a community is influenced by the state of the ecosystems it depends on and by its social, institutional and technological adaptive capacity, as well as by its level of awareness on climate change risks.

Climate change may increase the emergence of diseases that were previously under control or had already disappeared, and also the geographic and altitudinal expansion of disease endemic areas. This is particularly true in the case of vector transmissible diseases, since vectors are highly sensitive to climatic variations. As a result, the incidence and prevalence of vector transmissible diseases is increasing.

In countries like Bolivia that have a high epidemiologic profile of contagious diseases transmissible by vectors, the human health vulnerability level to climate change is very high.

Box 2. Case Study: Malaria outbreak in the Lake Titicaca Region

To assess the vulnerability of human health to climatic variability and extremes in a high semi-arid mountainous region, the cases of Malaria outbreaks in the municipalities of Mocomoco, Ancoraimes, Batallas and Carabuco were studied. In 1998 the disease impacted communities in this area that were not endemic of Malaria.

This study focuses on a retrospective assessment carried out for the period 1998 to 2006 in the communities of Tuntunani, Mollebamba, Caldera and Sehuenquera (see figure 4).

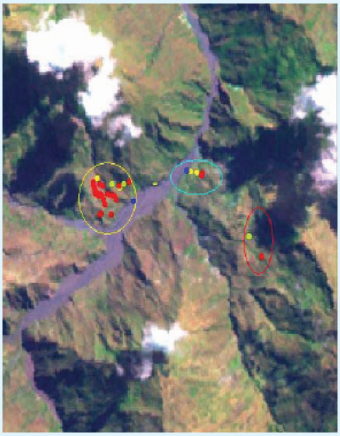

Figure 4. LANDSAT image that shows the location of Tuntunani (center in yellow), Mollebamba (blue) and Sehuenquera (red). The access to these communities is difficult.

During the rainy season in 1998 (between January and May) the Malaria outbreak affected 83 people (figure 5). The epidemic outbreak was caused by Plasmodium vivax reaching 8 communities in the area situated between 2,600 and 3,800m above sea level and about 50km away from the Lake Titicaca. Given the altitude, low temperature and the ecosystems in the area, neither Malaria nor other vector transmissible disease antecedents were previously recorded in the area. The majority of Malaria cases (52) were registered in the community of Tuntunani, representing about 20% of the total population of this community (250 inhabitants). However, data provided by the Andean Rural Health Council show that 93% of the population in Tuntunani had symptoms of the disease during the 1998 outbreak. The staff of the health centers that entered the community during that time confirmed that almost the entire population was suffering from the disease. According to the local authorities, 5 people died from Malaria in Tuntunani that year.

During the Malaria outbreak the local authorities and communities communicated the situation to the health centers in the area. The centers lacked the capacity and equipment to respond to this type of emergency, however, three medical campaigns were carried out in Tuntunani to evaluate and treat people suffering from the disease. Blood samples were sent to the Epidemiological Centre in La Paz to confirm the diagnosis (P. Vivax was positive).*

Surveys conducted in 2006 revealed that 71.4% of the population in the area knew about the Malaria disease locally called “Chujchu”. The local population identified the mosquitoes as vectors of the disease, however they believed that “Chujchu” was originally brought to the region by a person who died of the disease in 1998 and became infected with it in Alto Beni – a lowland area located in the northeast of the country and recognized as a Malaria endemic area.

According to the locals, mosquitoes in the area locally called “zancudos” appeared between 1990 and 1998. Studies conducted in the area from 1998 to 2006 suggest that the outbreak had a local character transmission because the infected people did not travel abroad in the year before the outbreak and because some of the people had two or more Malaria episodes during 1998. Moreover, the possibility of a local transmission is supported by the fact that the period when mosquitoes are typically present in the region (January to June) coincides with the period of the outbreak and the rainfall season (January to May).

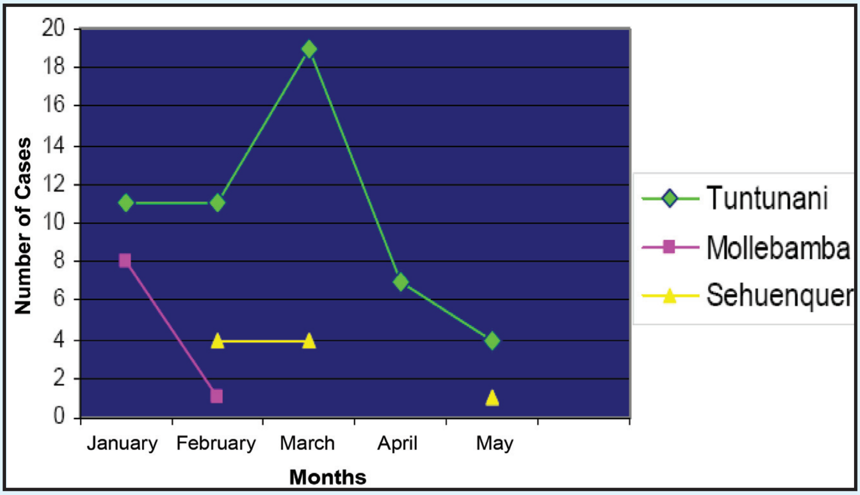

Figure 5. Malaria Cases in the Study Area between January and May 1998

The entomological monitoring carried out in the region recorded *Anopheles pseudopuntipennis* in communities within the area. Anopheline mosquitoes were identified in all their life stages and in both indoor and outdoor environments. According to the study, the local population is exposed to vectors when they are close to water bodies and wells but also when they are at home because the housing material and poor infrastructure is not suitable to protect the indoor environment from the vectors. Another factor that contributes towards the exposure of humans to vectors is the coexistence with animals that live near the houses or in some cases inside them.

The increase in temperature and rain intensity (within a few months) in the Lake Titicaca region could increase the vulnerability of the local population to vector transmissible diseases such as Malaria. The year 1998 coincided with the "El Niño" event 1997/98 that strongly impacted the region, causing an increase of the temperature and the rainfall concentrated within a few months. The outbreak of Malaria during the rain season is attributable to the climatic events of that year. This relationship has also been perceived by the locals involved in the assessment.

Between 1998 and 2006 new Malaria cases appeared sporadically in the area: 10 cases in 1999, 1 case in 2001, 2 in 2002 and 3 cases in 2005. These cases suggest an altitudinal and geographical expansion of the disease associated with climate change in the area that is modifying the ecosystems and creating suitable conditions for the development of vectors. As a result, areas in the high semi-arid mountainous region of Bolivia are becoming endemic for vector transmissible diseases.

* The use of medicinal plants and the services of traditional doctors (Callahuayas) is also part of the culture in the Lake Titicaca region. Nevertheless, an expansion of health centers in the area is facilitating access to "occidental" medicine in the region. Even so, the local population tends to mainly use traditional medicine. By consulting the population that suffered from Malaria in 1998 about the medicine used, 30.8% indicated that they used medicine provided by the health centers, and 69.2% stated that they used traditional medicine based on different plants.

In the specific case of Bolivia, this vulnerability is exacerbated by the existence of multiple ecosystems and microclimates with suitable conditions for the development of vectors in the country, as well as by the migration processes of people between disease endemic areas and areas that are not endemic. A preliminary evaluation at the national level estimated that climate change contributes to the development of 27.4% of Malaria cases (11.3% produced by *P. vivax* and 43.6% by *P. falciparum*). The assessment also established an increase in Malaria cases caused by *P. falciparum* since 1993 and in cases produced by *P. vivax* since 1994. The study estimated that Malaria will increase its endemic area between 12 and 20% over the next decade. As a preventive measure, the country has established a health network system with institutions working on vector transmissible diseases at national and local levels.

Table 4. Perceptions of the Effects of Climate Change on Human Health

Local Perceptions of the Effects of Climate Change on Human Health
Staff working in the local health centers have noticed that climatic variations (droughts, frosts and rain) are related to thermo oscillations that favor the development of respiratory infections.
The incidences of respiratory diseases have increased (acute respiratory infections, tuberculosis) and vector transmissible diseases have emerged.
The increase in temperature is causing problems with the skin and eyes of the population.
There is an increase of acute diarrheic diseases due to hygienic/dietary conditions. The main cause of these problems is the water scarcity in the region, which has become more severe over the past years, affecting water sources but also the agricultural production in the area.
Sporadic Malaria cases have occurred in the area.
People have died of Malaria in the area due to late recognition and diagnosis of the disease. This is because this area is not considered endemic of Malaria and the health centers and local population are not prepared to deal with this disease.
The health team stated that there is a presence of probable vectors that transmit Malaria in the area.
Lack of employment opportunities in the area oblige people to temporarily migrate to Malaria and Chagas endemic areas looking for work opportunities. Migrations can contribute to the transport of vectors that adapt to the conditions in the study area, particularly because climatic conditions have been changing and may now be suitable for their development.
The Malaria and Chagas monitoring system in the area is insufficient and only covers the areas that have presented epidemic cases of Malaria over the past decade.

Over the past decade, the combination of climate change, migration patterns and other previously mentioned factors has resulted in the outbreaks of local vector transmissible diseases in areas that have never had these diseases before and are not considered endemic areas. Such is the case of Malaria outbreaks in the Lake Titicaca region (see box 2). The impacts of such epidemics are significant given the precarious health system in the area, high poverty incidence, difficult access to communities, deficient building materials and housing infrastructure, and exposure to a new disease that is not typical of the region and for which the population has not yet acquired immunity. As a result, the human health vulnerability of the communities in this region to this type of diseases is very high and can result in death if preventive measures are not implemented in time. The health network system established in the country contributed to the human health vulnerability assessment of the local population in the study area, and will play a central role in the implementation of adaptation measures to reduce risks that climate change effects have on human health. Table 4 summarizes the perceptions of the staff working in the local health centers of the effects of climate change on the human health of the communities in the region.

3.3 Description of the Vallegrande Region

This region covers three provinces, the province of Vallegrande, the province of Manuel Maria Caballero and the province of Florida, as well as 11 municipalities. The study was carried out mainly in three municipalities: Moro Moro, Vallegrande and Saipina. The physiology of the study area comprises different altitudinal ecological zones: the head of valleys or high dry valleys located between 2,200 and 3,300m above sea level; the low dry valleys between 1,500 and 2,200m above sea level; the flat plains between 1,100 and 1,500m above sea level; and the sub-tropical humid zones between 460 and 1,100m above sea level. The physiographic characteristics of the region correspond to varied landscapes that expand without any sequential geographic order forming alluvial plains, terraces, hillsides, highlands, slopes, hills and mountains with different geological fragility. In hydrographic terms, the study area is part of the Amazonian Basin and the Grande River Sub-basin that is a tributary of the Mamore River.

3.3.1 Climate in the Vallegrande Region

The meso-thermal sub-humid dry climate is predominant in the region with low levels of water in the rainy season and water shortages during the dry season. Due to the different geographic characteristics of the region, the climate varies for the different localities within the area. In general terms, the average minimum temperature ranges between 6.8 and 15.5°C and extends from April to August (winter). The maximum temperature average ranges between 21.1 and 26.2°C and is applicable from October to March (summer)[5].

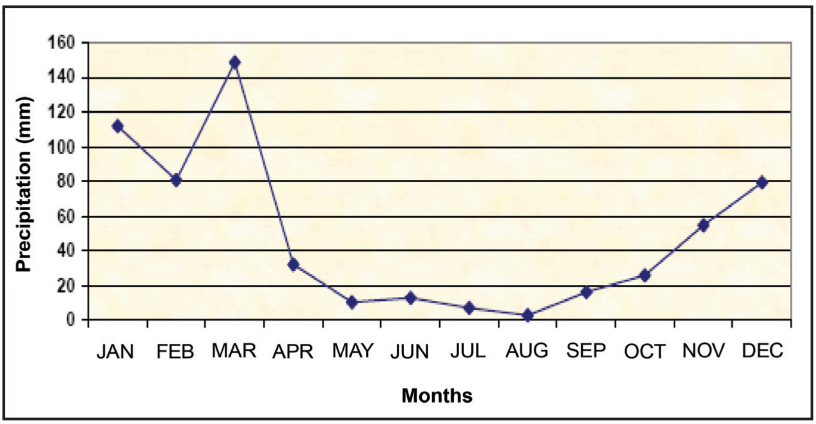

Figure 6. Monthly Precipitation Average in the Vallegrande Region (1971-2001)

The rainy season in the Vallegrande region begins in October and can last until April. During this period, and in particular between January and March in the past two decades, some areas such as Postervalle and Masicuri present occasional flooding problems. The average monthly precipitation

5 Data provided by the Research Center for Tropical Agriculture (CIAT) Meteorological Station in Vallegrande.

(1997 to 2001) is presented in figure 6. The relative humidity average in the region varies between 60 and 70%, presenting significant differences between the months of winter (low level of humidity) and summer (high level of humidity).

The predominant winds in the region come from the north with an average velocity that ranges between 5 and 15km/h. During the dry season (winter) wind can come from the south for short periods and with high velocities reaching 50km/h. This wind is cold and causes a decrease in temperature in the region. This event is locally known as "surazo" and can cause drought or drizzle. The latter benefits the crops cultivated during that period.

3.3.2 Ecosystem Diagnosis

The objective of ecosystem diagnosis is to assess the state of conservation of the ecosystems in the region and to identify elements that can contribute towards the monitoring and generation of information associated with climate change and the potential implications on socio-economic systems and human health in the area. To carry out the diagnosis, an area with ecotonal features within the study region was selected because these areas are considered to be the most sensitive to climatic variability. Consequently, the study focuses on two provinces of the region and 4 localities: the province of Manual Maria Caballero and the locality of San Rafael; and the province of Vallegrande and the localities of Alto Seco, Piraymiri and Chañara.

Changes in the State of Conservation of the Ecosystem and the Implications for Human Health and Food Security

The study area is located in the low sub-Andean dry valley altitudinal ecological zone (below 2,000m above sea level) and the vegetation in it can be divided in two main groups: 1) vegetation of the xeric inter-Andean valleys and 2) vegetation of the mountainous areas with periodic rain. The vegetation of the first group growing on soils with poor drainage is composed of riverside vegetation currently threatened by agricultural expansion and cattle breeding. The vegetation growing on well drained soils is composed of semi-arid inter-Andean forests currently threatened by the expansion of cattle farming. The vegetation of the second group includes mainly humid forests, sub-humid forests and riverside vegetation. The humid forests are currently exploited for wood extraction and agricultural expansion. The sub-humid forests are generally in a good state of conservation but are occasionally affected by fire that comes from adjacent areas. The riverside vegetation in narrow valleys is in a relatively good state of conservation, while in broad valleys it is threatened by agricultural expansion.

Potential Bio-Indicators for Climate Change

It is recognized that climate change will affect aquatic ecosystems transforming them from permanent into seasonal systems, thus impacting biodiversity and biogeochemical cycles. The magnitude of these impacts cannot yet be estimated with precision. The most affected ecosystems will be lakes, lagoons, rivers and streams in mountainous regions (1,600 to 2,500m above sea level), coastal wetlands and ecosystems that depend heavily on the underground water. In this study, different species of flora and fauna that depend on aquatic ecosystems were identified in the region. Based on the observations obtained in the field, the considerations mentioned above and the sensitivity level of the identified species to climatic variability and water availability, some of the species are suggested as potential bio-indicators to be included in a long term (> 15 years) climate change monitoring system.

As part of the group of fauna species that have potential as bio-indicators for climate change, a total of 47 species are suggested. The most important species groups for the study area are the lepidopteron, the macro-benthonic, amphibians and aquatic birds. Although one way of carrying out the monitoring is assessing the effects of climate change on each species, the study suggests evaluating the effects by assessing the biological interactions, not of one species but of a group of species. The following outlines the species that the study suggests as bio-indicators of climate change.

In the study area a total of 164 species of insects were identified corresponding to 3 orders (Lepidoptera, Coleoptera and Hymenoptera), 40 families, and 140 genuses. The presence and relative abundance of the insects identified in the area does not allow for defining their quality as biological indicators, with the exception of the lepidopteron (Nymphalidae, Papilionidae, Morphidae and Ithomidae). Indeed, to state that these species are good bio-indicators for climate change it is necessary to observe these species for a longer period of time. With this in mind, and based on the results obtained from field observations, the study suggests two species of the family Nymphalidae: *Anartia jatrophae* for high localities such as San Rafael and Chañara, and *Doxocopa cyane boliviana* for localities such as Alto Seco.

Among the macro-benthonic communities in water bodies, the study identified in both the humid and dry seasons 17 orders and 46 families in the phylum Nematodo, Annelida and Arthropoda. The macro-benthonic are typical organisms of aquatic substrates; they are sedentary, of broad distribution, and highly sensitive to physical and chemical changes in water. Moreover, they have long aquatic life stages, their taxonomy is well known and stable, and they are easy to capture. These characteristics make these organisms ideal bio-indicators of water bodies with a high sensitivity to environmental changes. In some circumstances, the assessment of these organisms exceeds the quality obtained from chemical evaluations because it integrates the effects caused by environmental variations in the past and therefore considers cumulative effects. Moreover, the monitoring of these organisms provides a high level of reliability. For these reasons, this study suggests the assessment of these species as bio-indicators for climate change. It also recommends assessing them using the tropic index. This means monitoring the proportion of the macro-benthonic species at each tropic level and the taxonomical composition of the community to evaluate the effects produced by climate change.

Fish communities in the study area are distributed in a heterogenic manner. As a result, each river has its characteristic species measured in terms of abundance or restriction in the distribution area. One of the most diverse fish in the region is the Characidae. They are predators and detritus in the trophic chain, which gives them an important place for the stability of aquatic ecosystems. Therefore this study suggests monitoring the composition and abundance of the Characidae as a possible bio-indicator of climate change.

In the study area a total of 15 species of amphibians and 16 species of reptiles were recorded. The identified reptiles represent species of dry environments, while amphibians represent typical species of semi-humid dry environments. The amphibians identified in the study are restricted to humid environments such as rivers, streams and lagoons, which determine their distribution. These environments are currently the most threatened ecosystems in the study area due to deforestation, expansion of agricultural activities and use of agrochemicals and industrial waste disposal. As a result, amphibians are one of the most vulnerable species in the area. In addition to the pressures placed on their habitats, amphibians are threatened by a new infection not yet intensively studied that is produced by a fungus and causes their death by asphyxia. Given the high sensitivity of amphibians to climatic factors, the study suggests some species as potential bio-indicators of climate change in the area: *Bufo arenarum* and *Hypsiboas andinus* for San Rafael; *Bufo arenarum* and *Hypsiboas andinus* for Chañara; *Dendropsophus minutus*, *Hypsiboas andinus*, *Hypsiboas marianitae* and *Odontophrynus americanus* for Alto Seco. Besides their sensitivity, these species are easy to sample and identify facilitating the monitoring process.

The bird observations carried out in the study area identified a total of 240 species of which 40 are included in the Convention on International Trade in Endangered Species (CITES). Climate change can reduce plankton and fish availability in water bodies affecting the food sources of aquatic bird species and reducing their success of reproduction and the number of eggs as well as affecting the survival of chicks and reproductive adults. Therefore, the study suggests monitoring the behavioral and population changes of 17 aquatic bird species identified in the area considered potentially good bio-indicators to assess climatic variability and change.

For mammals, the study recorded 31 species distributed in 18 families and 8 orders. This number of species does not represent the real biodiversity in the region, since chiropterans and rodents were not included in the sampling. The focus is placed on large mammals (generally carnivores) because these contribute towards determining the state of conservation of the studied areas[6]. Among the 31 registered species, the *Procyon cancrivorus* (karamaki) was selected as a potential bio-indicator for climate change monitoring due to its high dependence on humid environments and water bodies.

For the flora in the area, several bio-indicators were selected. In relation to the vegetation in the xeric valleys, characteristic species for each vegetation unit were proposed. In several cases, these represent the dominant species in each unit. The proposed species are: *Schinopsis haenkeana* (soto), *Neocardenasia herzogiana* (karapari), *Loxopterigium grisebachii* (cuchimara), *Cochlospermum tetrapterum* (paper tree), *Prosopis alba* (thako), *P. kuntzei* (lanza lanza), *Ceiba boliviana* (toborochi) and *Pseudobombax andicola*.

With regards to the sub-humid and humid mountainous regions, species were selected based on their abundance and for being characteristic of a vegetation unit. The following species were suggested: *Phoebe porphyria* (laurel), *Juglans australis* (nogal), *Nectandra angusta* (laurel), *Cedrela lilloi* (cedro), *Myrcianthes mato* (mato), *Myrcianthes pseudomato*, *Siphoneugena occidentales* (guayabilla), *Tabebuia lapacho* (lapacho), *Blepharocalyx salicifolius* (palo barroso), *Parapiptadenia excelsa* (chare), *Tipuana tipu* (tipa) and *Erythrina falcata* (ceibo).

The monitoring system of the species suggested above also has to consider the following requirements: 1) the data collection of the physical environment, including the aquatic environment, and 2) the establishment of meteorological stations to record the climatic events. By including these requirements, an integrated analysis of the climatic variability and change and the obtained field data can be conducted. This in turn will contribute towards the development of suitable preventive measures to reduce the associated risks and potential negative impacts of climatic extremes. The list provided above is not definitive, but is a group of proposed species that are characteristic of the area and sensitive to climatic variations. Indeed, the bio-indicators to be included in the monitoring system can be modified according to the conditions of the localities selected for the assessment and their capacity to carry out the monitoring activities.

3.4 Livelihoods Vulnerability and Risk Perceptions in the Vallegrande Region

3.4.1 Production Systems Vulnerability

The soils in the Vallegrande region have alluvial origin. In general terms, the study reveals that a great portion of the land in the area is not suitable for agriculture. This is due to the soil capability classes in the region (see table 5 and annex 1), and soil erosion caused by unsustainable land use and management. Nevertheless, the production systems in the area can be improved by introducing more sustainable production practices complemented with a suitable irrigation system. This region also presents an area rich in flora and fauna diversity located in the zone near the Amboro National Park.

Table 5 indicates that soils with capability class I are absent in the area and only 5% of the land in the region presents suitable soils for intensive agriculture (Class II to IV). Moreover, pastures represent only 6% of the area. The soil classification suggests that a great part of the area is mountainous and more suitable for wildlife and watershed protection.

6 The felines identified in the area, in particular Puma yaguarondi and Oncifelis geoffroyi that were recorded in the four localities (San Rafael, Chañara, Alto seco and Piraimirí) are important indicators of a relatively good state of ecosystem conservation.

Table 5. Land Use Capability in the Vallegrande Region

Class	Ha	%	Recommended Use
II to IV	31,113	5%	Annual and perennial crops
V to VI	37,792	6%	Pastures and perennial crops
VII to VIII	604,387	89%	Wildlife and watershed protection
Total	673,292	100%	

The Vallegrande region not only has poor soils for agriculture, but also experiences problems related to erosion. On the flat plains where boundaries are well defined, the arable layer of the soil ranges from 20 to 40cm. The arable soils in the hills and mountains are even more superficial ranging from 15 to 20cm in depth despite having well developed profiles with soil horizons A, B and C well defined. Moreover, several localities in the Vallegrande region experience serious erosion problems. The municipalities have introduced few practices to recover and conserve degraded soils. One of the most common practices is reforestation with exotic species, often ending in poor results. Although there are institutions in the area working on this situation, local farmers do not commonly implement soil conservation practices. This problem is aggravated by the poor economy and the scarcity of suitable land available for agriculture in this area where production is mainly for personal consumption. The highly degraded soils are generally abandoned and used for pastures. Over-grazing is another problem in the region.

The conditions described above shape the vulnerability of the production systems in this region. The following section presents the results of the agro-climatology assessment, describes the production systems in the region and presents the local perceptions of the effects of climate change on the production systems and water resources, as well as some locally proposed adaptation measures.

Agro-climatology Assessment

In the Vallegrande region there are six main climatic hazards that affect the production systems including: winds, snow (once a year in the Municipality of Pucara), frosts, hail, drought and flooding (Municipal Development Plan Mancommunity Vallegrande 2002). The municipalities in high elevation areas such as Moro Moro have a cold climate influenced by the high altitude, soil type, and the scarce vegetation cover. In the municipality of Vallegrande the climate is temperate, while in the municipality of Saipina the climate is dry. The lower humidity in the valley plains cause a reduction in the vegetation growth rate and density, resulting in low levels of organic matter in the soil. The slow vegetation growth is exacerbated by the temperature differences between day and night. Given the physiographic and climatic characteristics of the region, the production systems in the region are highly vulnerable to climatic variability and extremes.

The winds in the region are predominantly from the north with an average velocity ranging between 5 and 15km/h. In the winter season the crops receive winds for short periods from the south. These winds locally called “surazos” can reach a velocity of 50km/h and can bring drizzle. Although these winds can contribute towards crops’ growth by increasing humidity, they can also damage the production if they are too strong. Surazos and other winds influencing the region can also be dry. This can accelerate evapotranspiration increasing aridity and water demand. Due to the small size of agricultural property in the region, production systems have not included tree plantations that could serve as natural barriers against the wind and protect crops.

The average precipitation in the region is 580mm concentrated between November and March. In the last 3 years rain intensity has been concentrated between January and February causing soil saturation. Rain has been scarce between March and April drying the soils and contributing to the proliferation of plagues with negative impacts on cultivated crops. In general terms, the region has a very high climactic variability: The period 1995/96 was dry and was affected by the "El Niño" event; the period 1996/97 was rainy and very humid; the period 1997/98 was dry and was affected again by the "El Niño" event; the period 1998/99 was semi-dry; the period 1999/2000 was semi-dry with frosts and hail; 2000/01 was rainy with floods; the periods 2001/02 and 2004/05 were semi-dry and were affected by the delay of the rain season, frosts and hail; and the period 2005/06 was rainy with favorable conditions for the production of corn in the region.

Among the above mentioned climatic hazards that affect the region, drought is considered to be the most significant by the local farmers. The soil is prepared for cultivation between March and June in Saipina and October and December in Moro Moro and Vallegrande. If the soils are not humid by then, the organic matter that contributes towards soil fertilization will not be sufficiently decomposed thus negatively affecting productivity. Moreover, if the soils are dry during sowing, the seeds will dry and germination will also be negatively affected. If drought affects the first development stage of the crops, this will reduce the resilience of crops to cope with frosts or plagues. If water is not ensured for crops at least until the flowering and grain building stages, then production is highly vulnerable and the probability of a good harvest is very low.

In summary, the production systems in the Vallegrande region are influenced by high climatic variability and threatened by several climatic hazards. Successful crop production in the study area is mainly determined by water availability. The scarcity of water resources increases the vulnerability of crops to climatic hazards such as frost, hail, drought and flooding. The lack of preventive measures implemented to reduce the impacts caused by climatic events results in a decrease in the productivity negatively affecting the local population.

Production Systems Assessment

To assess the production systems in the region and define different levels of vulnerability to climatic hazards, the area has been divided into 3 productive zones: the highlands, the areas at the foot of the hills, and the valleys. Each of these zones has a different production system.

Zone 1 (Highlands): In the highlands the production system is based mainly on agriculture. The most produced crops are potatoes, wheat, barley and oats. Production is based on traditional extensive agriculture and is mainly for personal consumption. The predominant crop in this zone is the potato due to its adaptability to the physiographic and climatic conditions.

Zone 2 (Foot of hills): The production systems in this zone are semi-intensive and can combine crops such as corn and vegetables with cattle breeding. Households in this zone have larger areas of land property and can therefore raise cattle for both dairy and meat production.

Zone 3 (Valley plains): Due to better soil characteristics and water accessibility in this zone, production systems in this area are intensive. The main crops are vegetables (especially tomatoes and carrots), potatoes, sugar cane, peanuts and others.

In general terms, the main crops cultivated in the Vallegrande region are corn, potatoes, oats, wheat, barley, peanuts and vegetables. Fruit such as peaches, prunes and apples are also produced in this area. On the flat plains, sugar cane is a very important crop due to its profitability. According to data provided by the local authorities, 95% of families cultivate corn, followed by potatoes (85%), vegetables (42%) and sugar cane (90% in the zone 3).

The main threats currently affecting the crops in the study area are plagues and plant diseases that have arisen due to an increase in climatic variability. Known plagues and plant diseases in the region have spread and new ones have appeared. On the one hand, higher temperatures and lower precipitation have contributed towards an increase of plagues. For instance, new climatic conditions in the area are contributing towards the development of "polilla" and "mosca blanca" that affect potato crops and vegetables. Although these plagues are more characteristic in the valleys, climatic variations in the region are causing their migration to higher areas. Farmers in these areas do not know about control measures for these plagues. Although Integrated Pest Management (IPM) techniques exist to control these plagues, these techniques are not developed for different environments and have to be adapted for the conditions in new areas. Moreover, the difficult economic conditions of farmers in higher areas complicate the implementation of control measures in the short term. On the other hand, higher rain intensity within a few months has contributed towards the development of pathogen agents that cause plant diseases. This is particularly serious on the flat plains where the occurrence of floods has increased problems with plant diseases negatively affecting production.

These regional problems caused by climatic hazards, such as plagues and plant diseases are exacerbated by deforestation and agricultural expansion in upstream areas of the micro-basins and riparian areas. Deforestation in these areas (see box 3) increases water runoff causing severe soil erosion. While soils in these upstream areas are losing their water retention capacity and fertility, the downstream areas are affected by flooding during the rainy season.

To conclude, over past decades the agricultural production systems in Vallegrande region have been affected by climatic and social changes. On the one hand, more intense and frequent climatic hazards have impacted production directly (e.g. droughts that restrict water availability for plant development) and indirectly (e.g. contribution to the emergence of plagues and pathogen agents). On the other hand, farmers have expanded and intensified production systems without considering the sustainability of ecosystem services and land use suitability. The combination of these factors increases the vulnerability of production systems in the area and puts the food security and socio-economic systems of local communities at risk.

Box 3. Deforestation for "Chancaca" Production

The use of firewood as fuel is the main factor causing ecological degradation in the region. To produce "chancaca", a product made out of sugar cane, wood is used as a combustion fuel. Five trucks of six cubic meters of wood are necessary to process one hectare of sugar cane. As a result, in the area of Saipina (zone 3 - Valley plains) the average annual deforestation for firewood extraction used in the "chancaca" production is equivalent of 360 to 400ha.

Local Perceptions:
Climate Change Effects on the Production Systems and Possible Adaptation Measures

Local farmers indicate that climatic variability and extremes are the main hazards affecting their production. They recognize that climate has become more unpredictable and that some indicators used locally to estimate climatic variations are not reliable any more. Plagues and plant diseases are identified as the second most important hazard affecting local production. Farmers state that although control measures are implemented, new plagues and diseases have appeared in the area.

Moreover, the local population acknowledges that unsustainable production practices and over-exploitation of natural resources are disturbing the local ecosystems and climate. They believe that water, forests and soil resources are used indiscriminately, and agrochemicals are used on the crop fields without proper restrictions. Deforestation, forest fires, and the over-exploitation of pastures are contributing towards the changes in the climate. Local farmers have noted that drought periods have become longer, rain is less frequent and the rainy season is delayed.

According to local farmers, the consequence of all these factors is a decrease in the productivity or the loss of the entire production. This in turn impacts on the local economy, food security of the families, and the health of humans and animals. Table 6 below summarizes local perceptions[7] of climate change and the associated effects on production systems and food security. It also lists some of the locally proposed adaptation measures.

Table 6. Local Perceptions of Climate Change and the Associated Effects on the Production Systems and Food Security, and Suggested Adaptation Measures

Local Perceptions	Adaptation Measures
Climate conditions have changed and are affecting crop production.	New crops with shorter growth period have to be introduced.
The climate conditions are suitable for the development of plagues in new areas which affects the crop production.	Integrated measures have to be developed in cooperation with the municipal authorities. Technical assistance is necessary especially for the production of resistant vegetables.
Changes in climate dry the soil faster and contribute towards water scarcity. As a result, there is not enough water availability to irrigate the crops.	New seeds can be introduced to improve the quality and resistance of crops.
Heat is more intense and drought periods are longer affecting dairy cattle.	Resistant breeds need to be introduced into the area.
The heat is also affecting pig production by increasing diseases and complicating breeding.	New feeding techniques and diets are necessary, in particular for the periods of food scarcity.
The rain is "out of season" disturbing agricultural planning. The rainy season starts in December and sometimes even in January affecting sowing and crop production.	Information networks and technological capacity to predict/estimate climate conditions are necessary in the area.
Sudden temperature changes are affecting the crops, in particular more frequent frosts. Frosts are not predictable anymore.	New varieties of crops that are resistant to climatic variations are needed. Information networks to alert farmers are needed.
Hail is more frequent in the area affecting the crops.	Varieties with shorter growth period have to be introduced.
Winds have become stronger and more frequent.	Farmers need to be trained in climate change related risk prevention.
Increase in water scarcity is affecting the production and causing migration to the cities.	Projects to improve the local production systems are necessary.

Water Resources Vulnerability

Given its physiographic characteristics, the study area is an important source of water resources. Available water resources are used by the local population for domestic purposes, cattle breeding and crop irrigation.

7 Local perceptions were gathered in workshops carried out with local stakeholders including local authorities and leaders, farmers and community members.

Table 7. Local Perceptions of Risks Affecting the Water Resources and Suggested Adaptation Measures

Local Perceptions	Adaptation Measures
Rain distribution has changed and rain water is insufficient for human and animal consumption, as well as for crop irrigation.	Funds are needed for the construction of small-scale reservoirs and irrigation systems.
Water quality is low due to dissolved solids and agrochemicals among others.	Proper systems for drinking water need to be developed in the area.
The number of water springs is decreasing and some water springs are now shared by humans and animals.	
Rivers used to have water throughout the year, but are now dry two months a year causing problems for cattle and crop production.	Policies to protect water sources have to be developed and measures such as reforestation need to be implemented.
Less available water for irrigation is affecting crop production, in particular potatoes and vegetables.	Community projects to collect water are necessary.
Conflicts for water resources are increasing among users and communities.	Implement rules and regulations to improve the distribution system and irrigation schedule.
Water scarcity is causing a reduction in the production (crops and cattle) affecting local food availability and monetary incomes.	Varieties and breeding that are more resilient to climatic variations need to be introduced into the area.
Production and food scarcity is causing the migration of families and increasing the vulnerability of children and animals to local diseases.	Systems to store grains have to be improved and varieties with shorter growth periods are needed.

The main sources of water are reservoirs in high areas, the rivers that cross several communities and water springs located near the hills. Among the most important rivers in the region are the Saipina River and the Chilon River. The main water sources for human consumption are water springs (60%), followed by streams (18%), rivers (9%), water reservoirs (7%), wells (3%), and others (1%). Water is brought from the water springs to the communities using a cement storage tank and underground pipelines that distribute water to the different households. Currently, all the communities covered by the study use this system, except for the community of La Tranca that has an open system. In general, the Water Committees in the communities do not properly treat the water with chloride. As a result, water resources can be contaminated with solid residues and agrochemicals, particularly if the water distribution system is open. Moreover, water used for consumption is generally not boiled causing parasitic infections among the population.

In the area, 95% of the communities do not have a sanitary system. Only the capitals of the Moro Moro and Vallegrande municipalities have sanitary systems, while in the capital of Saipina a feasibility assessment for such a system is currently being carried out. Also, none of the communities covered by this study have a sewage system, only some households and education centers have latrines.

The water used for crop irrigation generally comes from rivers and reservoirs. In Saipina, irrigation water comes from the Comarapa and Chillon Rivers where a water reservoir has been built. The water is transported from this reservoir to the crop fields using cement channels. The water supply is organized in shifts: each farmer has the right to 4 to 8 hours a day according to the size of their land and the distance to the reservoir. The further away, the fewer hours a farmer has to irrigate. The municipality of Vallegrande lacks a system for irrigation; however, a reservoir is currently under construction to ensure food security for the communities Tucumancillo and El Bello. While the municipality of Moro Moro also lacks an irrigation system, drip irrigation is being implemented in fruit tree plantations and water is collected in 180 small reservoirs constructed in this municipality.

Over the past two decades, some areas have flooded during the rainy season making access to the crop fields difficult, while during the winter season, river flows have reduced considerably drying over a period of two months. These events are relatively new in the area and have caused negative impacts on local livelihoods, especially in terms of food security. According to local stakeholders, some families that were not able to adapt have decided to migrate. Local communities feel vulnerable to water scarcity and urgently demand the introduction of measures to reduce associated impacts. They recognize the importance of strengthening the capacity to manage water resources and of improving local awareness of the sustainable use and protection of water sources.

Local authorities have demonstrated interest in implementing measures to protect water resources by facilitating reforestation and the development of irrigation systems to ensure food security in the region. Table 7 below presents the local perceptions of the climatic hazards threatening water resources and the associated effects on production systems and food security.

3.4.2 Human Health Vulnerability

Climate change effects disturb the hydrologic dynamics of the continental water systems causing dry periods with lower precipitation and wet periods with higher rain intensity. On the one hand, these alterations have negative effects on the native fauna and flora that depend heavily on aquatic systems and are highly sensitive to climatic variability. On the other hand, these climate changes can favor the colonization of species that are highly competitive and have a high environmental tolerance level. These species can become dominant after an environmental change and displace other species. Species that have these characteristics and are of particular interest to this study due to their biomedical importance are the ones that belong to the Anophelinae subfamily, considered vectors of diseases such Malaria, Dengue and Yellow Fever.

The Anopheline mosquitoes have a broad distribution and high adaptability to environmental stress. Larvae of these species can be found in rivers, lagoons, wells and any other places that can store water, for instance Bromelia leaves. The Anopheline mosquitoes also have a preference for lentic bodies that contain detritus and aquatic vegetation. Moreover, these mosquitoes have the capacity to colonize ephemeral environments, displacing competitors and predators.

Given the ecological characteristics of the Anopheline larvae and the effects of the climatic extremes presented above, a growth in the population of these species can be expected, as well as a widening of their distribution. These species may colonize rivers with low flows and high concentrations of dissolved solids in the dry periods, in addition to water wells and pools that appear in the rainy season. An increase in available habitats will contribute towards their reproduction and the abundance of adult individuals. As a result, the possibility of Malaria, Dengue and Yellow Fever cases may increase, as well as the emergence of new infectious diseases.

Another important biomedical species that could favor climatic extremes is the Triatomine bug. The Triatomines are vectors of the Chagas disease. Around 60% of the Bolivian territory is endemic of Triatomines. The endemic areas are generally located in geographic zones between 300 and 3,500 m above sea level. Approximately 3.7 million of the inhabitants in the country are at risk of infection and about 1.8 million are already considered infected. A change in the climate could cause a broader distribution of the vector and cause an increase in the risk of infection at the local and national levels.

Due to the situation described above, this study focuses on estimating the population variations of Malaria and Chagas vectors due to climate change in the study area. To do so, the vectors are identified over a year in the households located in the selected localities[8]. The results show that Triatoma infestans are present in all the localities, while Anophelines are less present.

According to the local population, the incidence of Malaria in the evaluated localities has decreased significantly over the past 5 to 6 years. Among the main reasons for this reduction are the fumigation programs in the area and local campaigns to prevent Malaria disease such as posters, messages on the radio and TV, and workshops. The establishment of local health centers, the reduction of medical treatment costs and easier access to information on vector transmissible diseases have also contributed to the control of Malaria incidence.

As a result of the local campaigns, local farmers in the evaluated localities fumigate their homes using the residual agrochemicals that were used in the field. It has been confirmed that the dose they use follows the recommendations provided by the campaigns. Given that the products used for household fumigation are the same as the ones used in the field, fumigations are carried out according to the agricultural planning of the area and follow the preventive control for the cultivated crops. Apparently, the fumigations have been effective for mosquitoes but not for Triatomine bugs.

Lastly, the study suggests that although it was possible to identify Triatomines and to a lesser extent Anophelines in the area, it is necessary to establish a long-term monitoring program to determine population variations of Malaria and Chagas vectors due to climatic variability and change.

3.5 Municipal-level Adaptation Strategies

In the first phase of the project the vulnerability to climate change effects of each study region was assessed and the most critical aspects affecting their subsistence systems were determined. With this information, baseline scenarios have been established that will serve to evaluate climate and biological changes over time as well as adaptive capacity in the pilot regions. Besides contributing towards the understanding of the bio-climatic systems in the study areas, the first phase identified organizations and institutions that can contribute towards building adaptive capacity in changing scenarios and vulnerable environments.

Based on the results obtained in the first phase of the study and using a participatory and integrated approach, adaptation strategies are proposed for each study region. Cause-effect diagrams ("fish bone" diagrams) were used to involve local stakeholders in the development of adaptation strategies. This graphic technique allows the defining of clear relationships between the problems identified in the first phase for each sector (production systems and human health) and the causes of these problems. Using this technique in different workshops[9], municipal-level adaptation strategies were constructed for each region.

In both study regions water resources are identified as the central theme around which to develop adaptation strategies. Water resource management integrates the identified climate change impacts, particularly in relation to the sustainability of livelihoods (food security). Additionally, production systems adaptation strategies involve land use planning, capacity building and organizational development, while human health adaptation strategies consider the improvement of health services, prevention of effects caused by environmental degradation/change of human health, awareness creation, and the integration of health policies into other sectoral policies. In general terms, the proposed adaptation strategies for production systems correspond (see figure 7):

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8 The study area covers 2 provinces and 5 localities: the province of Manueal Maria Caballero with the locality of San Rafael; and the province of Vallegrande with the localities of Alto Seco, Masicuri, Piraymiri and Chañara.

9 A workshop to conduct this activity was carried out in the Vallegrande region in December 2006 and in the Lake Titicaca region in February 2007.

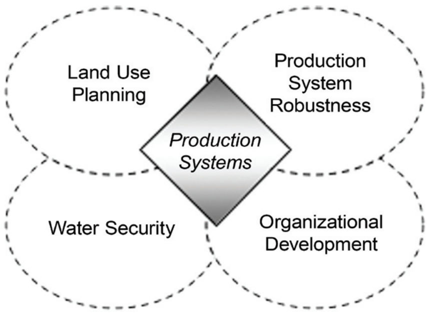

Figure 7. Categories for Production Systems Adaptation Strategies

Figure 8. Categories for Human Health Adaptation Strategies

Land use planning: refers to the identification of vulnerable and risk zones such as water recharge zones and wetlands and their protection through the establishment of Municipal Protected Areas.

Water security: refers to the preservation of water resources such as lakes, lagoons, water springs, rivers, wells, and wetlands. To do so, wetland areas have to be properly managed, recharge zones have to be protected and water has to be used more efficiently.

Production system robustness: refers to the production of resistant crops; the use of improved seeds better adapted to current climatic variability; the development of organic fertilizers; the implementation of integrated pest management systems; the introduction of sustainable production practices; the improvement of animal health management and the recovery of pastures.

Organizational development: refers to the development of community enterprises; engagement of entrepreneurs; community banking; agricultural insurance; micro-credit; and capacity development. The proposed adaptation strategies for human health systems involvPIe the following categories (see figure 8):

Proactive health system management: refers to a preventive epidemiological approach, it is aimed at strengthening the capacity of health centers and networks to successfully cope with the diagnosis and treatment of diseases that are sensitive to climatic variability and change. It also considers research capacity building; epidemiologic monitoring; the introduction of vector transmissible diseases as a presumed diagnosis even if these diseases are not in the traditional epidemiologic profile of the area; and the improvement of private and public housing infrastructure to reduce vulnerability to potential climate change related hazards on human health.

Environmental prevention and protection in the health sector: refers to environmental health projects and programs that improve sanitary aspects in all environmental systems.

Public participation and organization: refers to a well informed and educated population with the capacity to reduce their vulnerability to climate change effects and better adapt by reducing associated risks and preventing potential impacts on their health.

Moreover, to successfully implement the adaptation strategies, the study suggests incorporating climate change adaptation and risk management programs and projects into municipal government planning. Mechanisms to implement the proposed adaptation strategies include: Annual Operative Plans; Municipal Development Plans; Municipal Land Use Plans; and Municipal Climate Change Programs. Although the project supports the development of these strategies, they have to be implemented through the establishment of programs and projects approved by the Municipal

Councils through regulations to be executed by the Municipal Executives. Financial mechanisms and agricultural insurance systems can also serve as mechanisms to implement the proposed strategies. Finally, the municipal-level adaptation strategies described for each region in the following sections will contribute towards the development of the National Adaptation Plan and the Global Change Strategy under the National Development Plan.

3.5.1 Adaptation Strategies for the Lake Titicaca Region

Adaptation strategies suggested for the Lake Titicaca region are in line with the categories presented in the section above and focus on sustainable management of natural resources (particularly water resources) to prevent impacts caused by climate change on production systems (livelihoods) and human health. Table 8 presents the strategies proposed to help build adaptive capacity in this region.

Table 8. Adaptation Strategies for the Lake Titicaca Region

Land Use Planning
Mechanisms to support the development of Municipal Land Use Plans are assessed to establish a normative framework to use the land according to the soil capability, introducing sustainable practices, and incorporating risk prevention management.
Strengthening of Socio-economic Organizations
Strengthening the capacity of social and economic organizations includes: primary production diversification with introduction of improved technology; seed management and phytosanitary measures improvement; introduction of new breeds of flora and fauna; water, soil and forest resources management and conservation; support from micro-credit systems; and promoting community participation to implement adaptation strategies.
Ecological Production
Support is given for the development and consolidation of organizations that adopt eco-friendly production practices. To conserve and reduce the pressures placed on natural resources, capacity building, training and technology is provided to local farmers. Moreover, local production is enhanced to reduce food security vulnerability.
Conserve Water Springs, Water Courses, Wetlands, Pastures and Soil
The local population is trained in conservation of water resources and is aware of the importance of improving the management system of these resources and ensuring their equal distribution. Water supply systems are improved for human consumption (coverage and quality). Synergies with other programs and projects working on soil and wetland conservation are achieved. Wetlands and pastures are used according to their carrying capacity.
Proactive Health Systems Management
Local prevention strategies to reduce climate change impacts on human health are developed. Epidemiologic vigilance systems are established for diseases that are sensitive to climatic variability. Staff working in local health centers are trained to implement measures that improve the environmental health in the area and to develop research into this topic.

3.5.2 Adaptation Strategies for the Vallegrande Region

Adaptation strategies suggested for the Vallegrande region relate to the categories presented in the section above and focus mainly on natural resources conservation (in particular water resources) as the central theme to creating adaptive capacity in the region. On this basis, the following adaptation strategies are suggested (see table 9).

Table 9. Adaptation Strategies for the Vallegrande Region

Training and Awareness Raising
Local population is trained about the current and potential impacts caused by climate change on human health, water resources and production systems, as well as about the appropriate ways to react to, and prevent these impacts.
Land Use Planning
Mechanisms to support Municipal Land Use Plans and risk maps are developed and implemented.
Pesticides Management
Synergies with the Persistent Organic Compounds Program and other organizations working with pesticides in the area are achieved. Experiences and information on Integrated Pest Management (IPM) are shared and IPM practices are incorporated into the Municipal Development Plans.
Endemic Diseases
The national program on Malaria and Chagas supports the development of adaptive capacity in the region reducing human health vulnerability to these diseases. Moreover, other mechanisms to improve water quality and solid waste management are developed.
Environmental Education
The local population is educated on climate change and the associated impacts on human health.
Forest Resources Protection
The forests in the region are conserved and ecosystem services used sustainably. By conserving the forests, water springs are protected, floods are prevented, food security and human health are improved and biodiversity is conserved.
Capacity Strengthening
Municipalities are provided with better meteorological equipment, laboratory material, and geographical information systems and improved technical capacity.
Research and Management
Research institutes are involved in the development of adaptive capacity in the Vallegrande region.

3.5.3 Activities to Help Build Adaptive Capacity

Different activities have been planned for the six municipalities that compose both study regions. The activities are framed within the adaptation strategies explained above. Table 10 lists the 14 activities prioritized by the local authorities to help build adaptive capacity in the municipalities.

Table 10. Prioritized Activities to Help Build Adaptive Capacity in the Municipalities

No.	Activity	Municipality	No. of Families benefited
1	Introduction of improved potato varieties	Ancoraimes	120
2	Revitalization of broad bean production systems in the areas surrounding the Lake Titicaca	Carabuco	70
3	Capacity building by 70 promoters and environmental leaders	Carabuco	70
4	Capacity building in soil and water resources management and conservation	Batallas	120
5	Biomass production in wetlands cultivating white clover	Batallas	120
6	Capacity building by the staff working in health centers in the identification of epidemiologic indicators related to climate change	Ancoraimes	50
7	Implementation of social vigilance networks in charge of monitoring vector transmissible diseases that are sensitive to climate change	Carabuco	25
8	Promotion of organic vegetable production to reduce the use of pesticides	Vallegrande	10
9	Capacity development of Chagas disease prevention activities	Vallegrande	176
10	Capacity development and implementation of preventive measures to control and create awareness of Chagas disease	Saipina	250
11	Promotion and construction of ecological ovens	Moro Moro	210
12	Capacity building in and implementation of preventive measures to control and create awareness of Chagas disease	Moro Moro	881
13	Pilot project development to promote ecological ovens	Moro Moro	320
14	Strengthening in community organizational capacity	In all the Municipalities	

Activities to Help Build Adaptive Capacity in the Human Health Sector

The process to help build adaptive capacity in the health sector of both study regions started with the identification of institutions that could play a key role in the implementation of adaptation measures. After establishing inter-institutional agreements with these institutions that included local health centers, adaptation strategies and activities were developed with the active participation of local stakeholders and these institutions. The following describes the activities conducted under the categories that encompass the strategies to develop adaptive capacity in the human health sector:

Proactive Health System Management

Through workshops and seminars carried out in both regions local perceptions of climate change effects on human health are first collected. Once this stage is completed, local stakeholders, staff working in local health centers and Vector Information Points (VIPs), as well as local authorities and managers of the health network system covering the study areas are trained in the potential climate change impacts on human health and climate change related epidemiologic diagnosis and monitoring. This initiates a social process that enables a better understanding of the topic, the identification of the main impacts and causes in each region and the development of local adaptation strategies to reduce negative climate change effects on human health in each region.

Environmental Prevention and Protection

To reduce the impacts of environmental change on human health, monitoring activities of the natural systems are conducted with the local communities. The focus of the monitoring activities is to identify Malaria and Chagas vectors in the study regions. To do so, local staff working in the health centers and VIPs are trained in entomological monitoring. The different monitoring activities confirm that vectors are expanding their distribution area and pose a threat in new areas that were not considered endemic. For example, Malaria vectors are identified over 3,700m above sea level in the Lake Titicaca region. The local climatic variability suggests that this trend may continue over time and that Malaria vectors may reach the central area of the Bolivian Altiplano. Monitoring activities are complemented with questionnaires[10] to collect information of local perceptions and potential human exposure to vectors in the local communities.

In addition to monitoring activities, local communities receive training on vector control measures. Moreover, a proposal for a new regulation on "healthy housing" is developed using better material and infrastructure for the construction of housing in both regions. New housing models are designed based on the characteristics of each region, diagnosis of current housing conditions and the requirements needed to prevent indoor vector intrusion. This proposal is shared with staff working in local health centers and municipal authorities. To create awareness of this topic among the local population, questionnaires are conducted on the relation between housing, vectors and Malaria and Chagas cases in the communities.

Finally, another activity under this category is raising awareness among the communities of the importance of protecting natural systems as a preventive measure to reduce hazards threatening human health. To do so, topics such as the use of pesticides, mining contamination, waste disposal and hazardous waste management and the effects these activities have on human health are discussed with local stakeholders.

Public Participation and Organization

The adaptation activities conducted in line with this category aim at developing, in collaboration with the local stakeholders, a social change in the communities to restrain the propagation of diseases that are sensitive to climatic variability. Workshops are carried out to create awareness among the locals about climate change impacts on human health. Some communities have developed "Epidemiologic Vigilance Committees" aimed at monitoring climate change impacts upon sanitation. For the successful development and functioning of these committees and local information sharing on the topic, the support provided by the VIPs and health centers is fundamental.

10 A total of 150 people in the Vallegrande region and 100 people in the Lake Titicaca region participated in the questionnaires.

Activities to Help Build Adaptive Capacity in the Production Sector (Food Security)

To help build adaptive capacity in the production systems in the Lake Titicaca and Vallegrande regions, different activities are prioritized and conducted by the municipalities (see table 10). While the municipalities in the Vallegrande region focus on developing ecological ovens, the municipalities in the Lake Titicaca Region focus on increasing the resilience of productive systems and improving the management of natural resources. The activities are developed based on a “Learning by Doing” philosophy, where beneficiaries become involved in a cyclic learning process by carrying out the activities and then reflecting on the results to improve and continue with the process of increasing the production and improving the production systems’ resilience to climate change. The following summarizes the activities carried out to help build adaptive capacity in the production sector in the Lake Titicaca region.

Revitalization of Broad Bean Production Systems in the Areas Surrounding the Lake Titicaca

As mentioned above, the production systems in the Lake Titicaca region are vulnerable to climatic hazards such as droughts, frosts, hails, etc. The impacts of climatic variability and change on these systems affect the food security and income generation of local communities. To prevent these impacts and build adaptive capacity to climate change, the communities that surround the Lake Titicaca in the municipality of Carabuco decided to increase the resilience of their production systems by improving the broad bean production in the area. Broad beans are a suitable crop for these communities, because the lake contributes towards generating a micro-climate that provides the optimal conditions required by this crop to develop.

To improve the production, the broad bean variety “Gigante de Copacabana” is used and local knowledge of this crop’s management is strengthened. Firstly, farmers and farming associations establish productive agreements. Secondly, soil is prepared in plots selected using traditional technology. Thirdly, workshops are carried out to train farmers in seed selection and management, improved production techniques, and phytosanitary control, and technical assistance is provided during crop development. Fourthly, meetings to share experience are organized among the farmers participating in the project and between these farmers and farmer associations located in other areas of the region that have extensive experience in the production of this crop, as well as in its post-harvest processing. Finally, training is given in business development, micro-enterprise management and accountability, marketing and commercialization.

Among the main results and lessons gained from the activity are: a more broad and open vision of different production options; the strengthening of farmer organizations and the establishment of productive agreements; the better understanding of market dynamics and product quality; the knowledge of techniques that can accelerate the crop development cycle and shorten the exposure to climatic hazards; and knowledge of processing and commercialization of the product that contributes to food security but also to income generation.

Introduction of Improved Potato Crops

Potatoes are the main crop produced in the municipality of Ancoraimes. As in other areas of the region, the production of this crop is threatened by climatic hazards and soil degradation. To increase the robustness of their potato production systems, the communities in this municipality have decided to introduce a new and improved potato seed, strengthen their organizational capacity and improve their sustainable production practices.

Different activities are developed in Ancoraimes to improve the potato production: workshops; sowing of new seeds; technical assistance in the production; capacity building in agro-ecological management of the crop (e.g. use of organic compost, soil conservation practices and integrated pest management) and in potato seed production under controlled environments.

The main results and lessons gained from this activity are the strengthening of productive and organizational capacities of the farmers in the communities, and improved knowledge of agro-ecological techniques and how to use these techniques to reduce the vulnerability of production systems to climatic variability and change while improving productivity.

Biomass Production in Wetlands Cultivating White Clover

One of the main characteristics of the wetlands in the municipality of Batallas is their capacity to support continuous production, representing the main source of food security and the main area for breeding cattle for income generation in the municipality. Families in Batallas have intensive, semi-intensive, and extensive cattle breeding systems. The majority (85%) work with traditional extensive systems of mixed production (cattle breeding and crop production). In general, the low technological level of the production systems and the degradation of the wetlands increase the vulnerability of families that depend on these production activities to withstand climatic variability and extremes that affect these areas. To improve this situation, the municipality has decided to introduce white clover as a species that will improve the biomass production in the wetlands and contribute towards the conservation of these areas. Additionally, they focus on strengthening the ability of farmers to manage and recover wetlands, and create awareness of the potential climate change impacts on wetlands and cattle production.

To conserve and improve the biomass production in wetlands, different activities are carried out in Batallas. Firstly, workshops are held to train farmers in the potential impacts of climate change on the area. Secondly, training is given to farmers on biomass production in wetlands and production techniques to cultivate white clover. Thirdly, participative workshops are conducted to raise awareness of the importance of wetlands for animals and soil, environmental protection, sustainable production practices, and soil conservation. Fourthly, a participative assessment is carried out to evaluate white clover productivity using known techniques to measure floristic composition and biomass.

The main results and lessons obtained from the process are from the pilot plots where white clover is cultivated: the identification of the best practices to obtain higher levels of biomass production in the area; a higher interest among the farmers of new forage species; the practical knowledge of alternatives to adapt to climatic variability and to reduce the risks on forage production for cattle breeding; a better understanding of the effects of climatic variability and environmental degradation on the wetlands and the associated consequences; and a higher awareness level of the importance of conserving wetlands to improve the conditions for cattle breeding and crop production.

Capacity building of soil and water resources management and conservation

Soils in the Altiplano present high erosion levels. In addition to erosion processes, soil degradation in this area is exacerbated by higher climatic variability negatively affecting food production. To deal with this situation, the municipality of Batallas has decided to develop alternatives adopting preventive strategies aimed at conserving soil and protecting it from erosive actions. To do this, conservation systems are developed using traditional knowledge that allows not only for the conservation of soil fertility but also for making better use of water resources and improving production thereby improving food security in the area.

Different activities are organized in the municipality of Batallas to improve soil and water resources management and improve productivity. Firstly, workshops are organized to explain the impacts of climatic variability and change on vulnerable production systems and to share experiences of soil and water resources management. Based on the "Learning by Doing" philosophy, soil and water conservation practices based on traditional knowledge are implemented in demonstration plots. Finally, the monitoring and final results are evaluated in participative workshops aimed at promoting discussion and learning.

The main results and lessons obtained from the process are: strengthening of 125 farmers who participated in the implementation of demonstration plots; better understanding of climate change effects and environmental degradation on production systems; development of conservation systems that are suitable for the region using traditional knowledge; and strengthening of organizational development to adopt preventive strategies to adapt to climatic hazards while improving the local production and management of natural resources.

Organizational Development
In both study regions there are institutions and associations that focus on building organizational capacity, strengthening the production systems, and improving the management of natural resources. Farmer associations play an important role in the municipalities as they have contributed towards improving the generation and distribution of income from production activities, as well as improving access to technical assistance and new and better markets. Farmer associations are generally associated with support institutions working in the area. In particular, in the Vallegrande region there are several local and international institutions working on different activities supporting the sustainable development of the families in the area.

In the Lake Titicaca region, institutions have not yet adopted adaptation measures to reduce the effects of climatic variability and change, while in the Vallegrande region the combined institutional efforts along with strong demand from farmers have resulted in the construction of numerous water reservoirs that could contribute towards coping with the negative effects of climate change. Also, soil conservation practices implemented in the Vallegrande region could serve as adaptation measures to climate change effects.

Considering the organizational development context in both study regions, some conditions can be identified as key factors for the successful implementation of adaptation measures and adaptive capacity building among the local communities: 1) the generation of a proactive vision in the institutions that can create the dynamics that allow for changes and flexibility to adapt to fluctuating conditions and higher climatic variability; 2) the decentralization of institutions to allow for more autonomous decision-making in relation to the local for adaptation; 3) the continuity of projects implemented by existing support institutions (in both regions there is institutional supply, but in the Vallegrande region the project continuity is better); and 4) the introduction of market-oriented strategies and an entrepreneurial approach to increase the adaptive capacity of the communities as opposed to the current state-/support-dependent character of the communities and farmers.

4. Lessons Learned

Building Adaptive Capacity

• Implement a positive approach. A positive approach entails focusing mainly on the capacities rather than on the vulnerabilities and problems. The existing capacities can be part of the solutions to face the challenges. A positive approach can therefore contribute towards finding potentials and opportunities for development. In this sense, resilience can be considered a positive way of looking at vulnerability. To implement a positive approach, the process needs to be based on the stakeholders' experiences and the current technical and institutional capacity to ensure sustainability in the capacity building process.

• Development from inside-out. Adaptation needs to go in harmony with the priorities of the communities, otherwise any technological solution proposed will not be sustainable. To achieve a continuous process of capacity building it is important to consider the following principles: 1) it is fundamental that the actors become the owners of the process and the process needs to develop in a way that the stakeholders perceive is the most appropriate regardless of if errors are committed; 2) the continuous involvement of stakeholders can increase the number of activities that can be conducted, therefore it is important to reach a consensus on the activities to be prioritized and the planning of activities.

- Snow ball process. The continuous involvement of stakeholders in the process motivates the social transformation needed to create adaptive capacity. Adaptive capacity building is a learning process that involves learning by doing and reflection along the way.

- The lessons learned on adaptive capacity building enrich the initial conceptual framework proposed for the project and allow for generating a more evolved and consistent framework. For instance, building adaptive capacity can help to understand that the concept of social capital can be enriched through the traditional activities and knowledge of the Aymara communities.

- Finally, building adaptive capacity is not only applicable for creating the capacity to cope with climate change effects, but also for reacting to other challenges and dilemmas, whether these are socio-economic, political or legal.

Production Systems Vulnerability and Adaptation

- Human actions exacerbate the impacts caused by climate change, increasing the vulnerability of natural and socio-economic systems. The impacts of climatic variability and change affect not only biodiversity, but also the sustainability of livelihoods. Livelihoods in the semi-arid mountainous regions are currently vulnerable and threatened by climate change effects directly and indirectly.

- Water access, agricultural production, food security and human health among others could be seriously affected if prevention measures are not implemented. Among the main prevention measures to reducing the impacts caused by climatic variability and change, the study identifies the protection and conservation of natural ecosystems, their components and services.

- In particular, the study identifies water resources to be the central theme in developing an adaptation strategy to climate change effects in the study regions.

Human Health Vulnerability to Climate Change

- Vector transmissible diseases, parasitic diseases, as well as acute diarrheic diseases and acute respiratory infections are highly sensitive to climatic variability. Climate change is causing an increase in the incidence of these diseases, their expansion into new areas and the emergence of new diseases. This is affecting the population, in particular children below 5 years of age causing high mortality rates.

- The methodology used to evaluate vulnerability in the health sector at the local level including an assessment of the bio-climatic system allows a more systemic analysis of climate change impacts on human health.

- The participatory approach and local development of adaptation strategies contributes towards a bottom-up process initiated by local communities and staff working in local health centers which will complement national strategies.

- The use of a participatory approach helps guarantee sustainability, as well as institutional and community acceptance.

Traditional Knowledge

- Traditional knowledge on climate estimation/prediction is maintained and commonly used in rural areas. This system is based on the systematic observation of indicators. However, predictions and indicators have become less reliable in the past decades and farmers claim this is attributable to the changing climate. As a result, farmers cannot plan agricultural activities as usual.

5. Strategic Recommendations

Recommendations for Public Policy and Institutional Capacity

- From a public policy perspective, the challenge is not only to build adaptation capacity, but also to recognize the existing or potential capacity of society to adapt. To do so, it is first important for state agencies and organizations to recognize the limitations of understanding reality with certainty and the implications this has for planning and management. Moreover, it is of great value to acknowledge a diversity of perspectives, knowledge and constructions of the world by the people who determine social reality. Finally, it is also essential to recognize the ability of the social and natural ecosystems to sense contingencies and react with innovative and adaptive strategies.

- Currently, in both study regions there is a lack of institutional coordination. Organizations are conducting studies independently and information is not properly shared. In workshops that were held, stakeholders pointed out the importance of ensuring more effective and permanent relationships between the different institutions working in the study regions. By doing so, the participation and agreement process will be strengthened thereby improving the national and local capacity to cope with climate change effects.

Recommendations for Subsistence Systems

- From an environmental and water security and management perspective, municipal authorities in cooperation with other social and economic actors need to invest in ensuring the sustainable and efficient use of water resources. In the Lake Titicaca region, it is important to increase the number of rain water reservoirs and to protect natural pastures. In the Vallegrande region, it is fundamental to protect water recharge zones (upstream areas of the micro-basins) and reforest these areas with native species. Also, measures to collect rain water and use it for irrigation need to be introduced.

- Concerning the development of new technologies, the National Institute for Agricultural Research can play a key role in the technological development in the study regions working in coordination with farmers, universities and the current foundation system. For the Lake Titicaca region, it is essential to work on technologies to improve the forage for dairy cattle, while for the Vallegrande region, the emphasis needs to be placed on reducing the over-exploitation of forests for firewood by providing alternative sources of energy.

- Also, it has been observed that Andean crop varieties that are more resistant to climatic variability can be introduced, improving productivity whilst contributing towards the conservation of soil and water resources. The successful results of cultivating these crops in demonstration plots could promote their broader use in the region.

- To achieve sustainable agricultural production and enhance food security it is fundamental to conserve the local biodiversity, incorporate sustainable production practices, and adopt a more ecological approach in the production systems.

- With regards to the finance and insurance systems, the National Development Plan establishes the creation of an agricultural insurance that should work in accordance with the context of each study region. Agricultural insurance systems subsidized by the national government and international cooperation could be implemented as an adaptation measure.

Recommendations for Human Health

- Currently, national policies promoted by the health sector in Bolivia are isolated and do not consider other sectors. It is necessary to develop national integrated policies that incorporate sanitary strategies into the other sectors, in particular into the environment sector. This would be the first step in the assessment of climate change impacts on human health and the planning of national integrated policies for adaptation.

- Health has been incorporated as a main issue into the National Adaptation Plan and an agreement with the Ministry of Health and Sports has been signed to implement adaptation measures to climate change in the health sector.

- Climate change needs to be a cross-cutting issue within the National Health System (NHS). To incorporate climate change and build adaptive capacity in the NHS six adaptation measures have been proposed: 1) mainstreaming climate change in health policies and programs; 2) generating proactive management in the NHS; 3) promoting social participation; 4) implementing environmental prevention and protection; 5) developing bio-climatic vigilance systems; and 6) developing current and future scenarios for human health vulnerability at the national level.

- Moreover, staff working in the health centers that compose the NHS need training and better equipment to treat diseases that are sensitive to climatic variability. This is important in endemic areas, but also in other areas that have become highly vulnerable due to the spread of diseases and emergence of new ones caused by climate change.

- At the local level, health insurance such as the Universal Insurance for Mothers and Children and the Old Age Insurance cover the study regions. The Local Health Network also covers the area with health centers that provide primary and secondary attention and mainly cover maternal and child health. These organizations need to be trained in the effects of climate change on human health and possible risk prevention measures, as well as being strengthened to improve their treatment and research capacity.

- Given the high vulnerability of human health to climate change impacts in the study regions it is necessary to implement adaptation measures that consider the improvement of housing infrastructure, capacity building and awareness raising.

- At the international level, the project contributed towards the discussions about climate change issues affecting human health at the Community of Andean Nations (CAN) and the Regional Health and Climate Change Plan of the Pan-American Health Organization. The experience and results obtained in building adaptive capacity at the local and national levels in the health sector could serve as a basis to provide insight on methodologies to implement adaptation measures at local level in the international debates.

Recommendations for the Use of Traditional Knowledge

- Traditional knowledge to predict/estimate climate conditions and plan agricultural activities based on systematic observation of indicators needs to be re-valued and recognized as complementary to weather and climate assessment methodologies that currently exist. Moreover, traditional knowledge could contribute towards building adaptive capacity in the areas.

- Due to difficult conditions in rural areas, a large portion of the younger population has migrated to the cities. It is important to re-value and share traditional knowledge with the youth that stay in rural areas through education centers and universities so that traditional knowledge is not lost over time.

General Recommendations for the Project and Further Steps

- Standardize the applied methodologies.

- Establish a database to be used as a reference and baseline in the evaluation of the bio-climatic processes and adaptive capacity in the study regions.

- Establish bio-climatic monitoring systems in the study regions based on the suggested bio-indicators to determine the relationships between climatic variability and change, the population behavior of selected species, and disease incidences.

- Share the generated information using a web-based tool with the national and international research community and decision-makers.

- Promote discussion and analysis of climate adaptation and the results obtained in the studies in the pilot regions to support decision-making and planning.

- Expand the coverage of the study and involve more municipalities.

ANNEX 1. Soil Capability Classification

The Land Use Capability Parameters of the U.S. Soil Conservation Services are used to classify the soil into the following capability classes:

Soil Class	Description
I and II	Soils suitable for agriculture and exploitation with acceptable yield.
III and IV	Soils have severe limitations for agriculture. The crops cultivated in these soils require more farm work for their successful development. It is more economical to use these soils for pasture and forest exploitation.
V	Soils are not likely to erode but have other limitations that are impractical to remove and that limit their use. These soils can be suitable for pastures.
VI and VII	Soils have severe limitations that make them generally unsuitable for cultivation.
VIII	Marginal soils not suitable for any agricultural activity or forestry. Areas that have these soils can be designated as protected areas.

Building Capacity in Two Vulnerable Areas of the Colombian Coastal Area

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1. Background

Adaptation was defined in 1992 by the United Nations Framework Convention on Climate Change (UNFCCC) as 'all adjustments in socio-economic systems designed to reduce vulnerability to climate change'. Since then this concept has evolved and gained relevance along with mitigation. Whereas mitigation refers to limiting global climate change by reducing greenhouse gas (GHGs) emissions and enhancing carbon sinks, adaptation aims at moderating adverse climate change effects through a wide range of system-specific actions at the local and the regional level.

The identification and implementation of sound adaptation strategies, however, is limited by the still poor understanding of the natural and socio-economic systems' responses to climate change effects. This generates uncertainties in the development of appropriate adaptation options that are economically efficient, technically and politically feasible, environmentally sound, culturally compatible and socially equitable. Adding to those challenges are that the costs and benefits of adaptation options, especially the non-technical ones, are difficult to measure and express in a common unit.

In developing countries, especially in the least developed ones and those most vulnerable to the effects of climate change, the capacity to adapt is generally much lower than in industrialized nations. This is generally due to a lack of financial resources, poor access to technological and scientific information, weak research and development capacity, the lack of highly skilled human resources, and weak institutional capacity. Moreover, national wealth and in particular its distribution play an important role in a country's capacity to adapt. In this respect, developing countries with a high poverty incidence are highly vulnerable.

The high vulnerability of developing countries is also due to the fact that climate change effects are generally not contemplated in their development planning, resulting in a visible lack of preparation to deal with the potential impacts of climate change. Sea-level rise (SLR) accelerated by climate change is one of the various effects to be considered by these countries because of the potentially negative impact it could have on their most vulnerable coastal areas.

Colombia is a developing country prone to the conditions and vulnerabilities described above. The first phase of the Netherlands Climate Change Studies Assistant Program (NCCSAP) that assessed the vulnerability of the Colombian coastal areas to potential SLR identified serious constraints for developing adaptation strategies in this country. The following summarizes these key constraints.

Firstly, legislative, institutional and organizational structures are highly vulnerable due to the lack of a normative framework that includes coastal zone management. Secondly, the economic feasibility of developing adaptation strategies is critically low, because the country is not prepared to assume the financial costs of implementing adaptation measures to SLR. Thirdly, the technical feasibility is also low due to the lack of technical capacity among institutions and scientific uncertainties on the subject. Fourthly, cultural and social vulnerability is high, because of the low quality of life conditions along Colombian coastal zones. Lastly, violent conflict that currently affects a large portion of the country negatively influences most of the development activities in the country.

The second phase of the Netherlands Climate Assistance Program (NCAP) was developed to identify adaptation strategies that could be successfully implemented in Colombia and build adaptation capacity considering the conditions and constraints described above. The approach of the second phase, however, varies in that it analyzes the situation from a local-level perspective. The second phase focuses on assessing the vulnerability and identifying adaptation measures to contribute towards the local adaptive capacity of two vulnerable areas of the Colombian coast: Cartagena de Indias (Caribbean coast) and San Andres de Tumaco (Pacific coast). Box 1 briefly presents the factors that need to be considered in order to build local adaptive capacity.

Box 1. Contributing towards Creating Adaptive Capacity at the Local Level

To identify adaptation strategies and contribute towards creating adaptive capacity at the local level, it is necessary to understand the local context including the state of the natural systems, the population needs and living conditions, the productive systems, the socio-cultural organizations, the institutional capacity and the local management and development strategies. Although climate change effects such as SLR, can have large impacts at the local level, there is a general lack of awareness among local decision-makers and community members about these potential impacts and consequently about how to prevent them. Therefore, creating adaptive capacity at the local level requires the participation and involvement of local stakeholders including decision-makers, companies and community members. It is also important to increase the level of knowledge concerning the vulnerability of the local territory and the potential impacts of climate change effects so that stakeholders can use this information to take the necessary decisions and actions to prevent impacts and reduce risks.

2. Objectives and Methodology

2.1 Scope and Objectives

The second phase of the NCAP follows the guidelines of the National Integrated Coastal Zone Management (ICZM) Policy which uses an integrated approach to generate effective adaptation strategies to implement at the local and national level. The objective of this study is to evaluate the vulnerability of key economic sectors to climate change effects in the Colombian coastal area and to identify strategies to build capacity to cope with potential SLR-related impacts (see table 1). To do so, the study adopts a local-level approach and focuses on two vulnerable areas of the Colombian coast identified in the first phase of the NCAP project as critical areas with the highest capital value at risk due to potential SLR. The study first conducts a sectoral vulnerability assessment in each area (considering tourism, agriculture and fisheries), with special focus on the population living in poverty conditions. It then identifies suitable adaptation measures and strategies within the framework of the National ICZM Policy. The project also generates public awareness and builds adaptive capacity through meetings and workshops with the different stakeholders. The results of the study are expected to set demonstrative pilot actions to prepare the country for the development of a National Policy on Climate Change Adaptation.

Table 1. Second Phase NCAP-Colombia Objectives

General Objective
To evaluate the vulnerability of key economic sectors to climate change effects in the Colombian coastal area and to identify strategies to build capacity to cope with potential SLR-related impacts.
Supporting Tasks
• To assess the sectoral vulnerability of two selected coastal areas, with special focus on the population living in poverty conditions. • To identify and analyze possible adaptation measures and strategies within the ICZM Policy framework. • To generate public awareness and build adaptive capacity through meetings and workshops with the different stakeholders.

According to the guidelines established under the ICZM policy, an integrated assessment of the study areas is carried out by evaluating potential biophysical, economic and social impacts due to SLR. Serving to meet both the capacity building and adaptation goals, stakeholders are engaged in the development of the project. In the study, the primary stakeholders are those considered to be the most affected and vulnerable populations to climate change risks for a specific human system. As such, they are seen as the direct beneficiaries of the project. The secondary stakeholders are those who are able to influence the success or failure of the project.

2.2 Methodology

The methodology used in the project (see figure 1) combines the adaptation framework proposed by Klein and Nicholls (1999), the UNDP-GEF Adaptation Policy Framework (2003), the DINAS-COAST project methodology, and the Framework for Planning and Decision-making Process proposed by Sharifi et al. (2004). The framework recognizes that local-scale strategies should be consistent with and inform national-scale policies. The framework also assumes that systems change over time, and that vulnerability and adaptation capacity to current experiences will not necessarily be the same in the future.

Figure 1. Methodology Framework NCAP-Colombia

Under this framework, an initial review and description of the system is first conducted. Then a vulnerability assessment is developed to analyze potential impacts upon the system. A scenario development process is also included in this stage. An adaptation decision matrix is then applied to identify and assess alternative policy options that respond to different adaptation measures to SLR. Finally, a policy exercise approach is conducted to downscale national policy options that reduce climate risks at the local level. Finally, the identified adaptation strategies are analyzed and the most suitable ones are selected.

System description: The first stage of the methodology examines the biophysical and socio-economic systems of the study areas to identify current problems and opportunities. Descriptions of current economic activities, especially those activities that increase vulnerability to climate risks are also included. In general, the system description is based on existing assessments and published and available studies, expert judgment and stakeholders' feedback. Efforts were made to use the most recent and updated information sources.

For the biophysical component of this stage, the main sources of information are previous studies carried out in the study areas. These provided sufficient information to gain a general idea of the current state of the natural systems. Stakeholders also provided feedback on this information and assisted in identifying current pressures on the natural system. These pressures were identified with the stakeholders through a problem analysis carried out for each area based on the Driving Force, Pressure, State and Impact - DPSIR methodology. As a result of this analysis, the stakeholders recognized the need to reduce the study area for Cartagena. It appeared that the administrative limits were considered to be too complicated to manage because of the large differences and variety of issues and pressures threatening the area. The study area was therefore limited to the portion of territory between La Boquilla (the northern limit of the Ciénaga de la Virgen) and the urban area of Cartagena, including the Cartagena Bay system.

The description of the socio-economic system of Cartagena is based on secondary information available on-line, as well as on statistical and analytical documents. Unfortunately, studies that analyze the current socio-economic situation of Tumaco were not found.[1]

The first stage of the methodology contributed towards the development of a current scenario for each study area that led directly into the vulnerability assessment.

Vulnerability Assessment: The second stage of the methodology focuses on the vulnerability assessment of the natural and socio-economic systems of each area. For the natural systems, the term susceptibility was preferred as it refers to the degree to which a system is open, liable, or sensitive to climate change effects. This approach considers the system's natural resilience and resistance to damage, the risk of hazards and the acquired resilience. The environmental susceptibility index model assumes that resilience is greater for a system that is less damaged. The susceptibility depends not only on the systems' characteristics, but on other pressures imposed upon the system as well. Box 2 explains the vulnerability and resilience of a natural system within the SLR context. The socio-economic vulnerability, on the other hand, refers to the society's economic, institutional, technical and cultural ability to prevent or face changes in the socio-economic system.

Box 2. Vulnerability and Resilience

Within the SLR context, vulnerability of the natural system can be referred to as the effects of an event on a given ecosystem and the capacity of this ecosystem to survive over time. This survival capacity depends upon the ecosystem's ability to recover quickly from shock, injury or depression (resilience). It is important to note that resilience can either be natural (intrinsic to a given system) or acquired (if it is gained from previous damage). Therefore a natural system's vulnerability is decreased as its resilience increases.

The vulnerability and susceptibility of the coastal areas of Cartagena and Tumaco are assessed from two different approaches: 1) considering current circumstances without taking into account the possible effects of SLR; and 2), considering different scenarios that include socio-economic changes and different levels of SLR.

1 For the vulnerability assessment this gap was complemented with primary information collected in a fieldwork campaign conducted in Tumaco.

Firstly, the natural system's susceptibility was calculated using the information obtained from the previous stage, as well as expert knowledge and local stakeholders' perceptions. The overall susceptibility index is composed of six indicators (see figure 2, annex 1) used by the Colombian Environmental Information System (SIAC in Spanish). To calculate the overall natural susceptibility index (BSI) for each area, the results of each independent indicator were computed, resulting in a general numerical value for each case. Each indicator is weighted in accordance with the perceived importance allocated to each one of them. In general, the most important indicator is considered to be ecosystem quality, followed by ecosystem coverage. The other four indicators (water quality and hydrographic processes integrity, recovery areas, land use and hazards) receive the same weight as they are considered to be equally important in defining the natural systems' susceptibility in the studied areas. It is very important to understand the entire process given that the general value does not provide as much information as each indicator does by itself. While understanding the entire process is critical in defining the measures to be taken, the susceptibility index shows the extent to which the natural system is prone to damage and degradation. The larger the general value obtained, the more susceptible the areas are from a natural system's perspective. Annex 1 presents the values for the classification of the susceptibility into: high, medium high, medium, medium low and low.

Secondly, the causality analysis of the socio-economic and environmental problems in both study areas contributed towards the recognition of relevant variables to evaluate the socio-economic systems' vulnerability. The indicators for the socio-economic vulnerability index were selected considering the results of the DPSIR analysis conducted in the first regional workshop[2], as well as available information for each area. The socio-economic vulnerability index (SVI) is composed of 5 categories (see figure 2) and the following indicators: population indicator; public investment indicator; natural disaster risk indicator; human capital factor; and life quality indicator (includes sewage disposal, water supply, waste recollection, cooking fuel, house wall materials and house floor material). The socio-economic vulnerability index values are allocated in the range 0 to 100, an increase in the value indicates that the vulnerability diminishes. Annex 2 gives the values for the classification of the vulnerability into: very high, high, medium-high, medium, medium low and low.

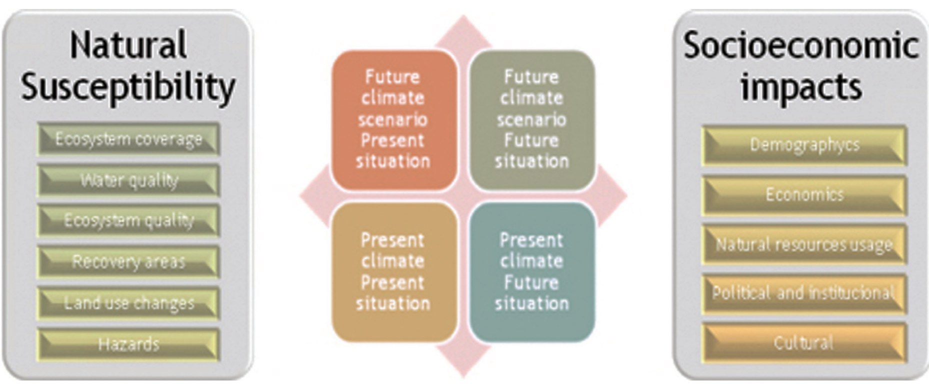


Figure 2. General Scheme for Vulnerability Assessment

The first susceptibility and vulnerability assessment only reflects the current state of the natural and socio-economic systems. To evaluate future possible situations, future scenarios are developed

2 The Driving Force, Pressure, State and Impact - DPSIR analysis was conducted in Cartagena during the first regional workshop with key stakeholders in July 2005. The DPSIR was used with two purposes: 1) to prioritize, based on the stakeholders' perception, the social, economic and ecological sectors that are currently vulnerable to extreme climate events and which could be at risk in a "business as usual" scenario; and 2) to establish a set of priority impacts that could serve to guide the selection of indicators on which to develop the capacity building and adaptation measures.

considering different changes to socio-economic and environmental characteristics and different levels of SLR. An important input to the scenario development process is the perception of the stakeholders in relation to the areas at risk of flooding due to an SLR.[3]

Scenarios extend to the year 2019. The reason for using this particular year is due to the Colombian national government's *Visión Colombia II Centenario 2019*. This document, which portrays the "Vision 2019", is an ambitious proposal that develops a long term vision of prosperity for the country. However, although it focuses mainly on the socio-economic aspects of development, many of these aspects have a direct or indirect effect on the environment. It is important to note that although scenarios extend to the year 2019, SLR levels are not projected for that year, but are based on the analysis of satellite images and risk maps for each area.

To summarize, while topographic characteristics are not modified for the development of scenarios, socio-economic variables and SLR levels are modified to gain a better understanding of the potential impacts of SLR on the selected study areas considering the susceptibility of the natural systems and the socio-economic system's vulnerability.

Adaptation Decision Matrix: The third stage of the methodology considers the information gained about the system's behavior in the previous stage and establishes a functional and structural relationship among major elements. The Adaptation Decision Matrix (ADM) is a tool used to relate given local circumstances to adaptation measures that are likely to be implemented in the short term, given the characteristics of the measures, the local needs and the institutional capacity. This process involves expert judgment and analysis carried out by the project team. It is implemented in an interactive manner, maintaining feedback with the stakeholders and following a step-by-step process to estimate the potential impacts for each policy adaptation strategy. The fields used in this matrix were developed based on different sources, but mainly on the Checklist and Database for Evaluating Adaptation Measures and Strategies, developed by the Stockholm Environment Institute (SEI). This tool facilitates recording the range of responses that make a policy option suitable and its implementation feasible for each specific area (see figure 3).

Figure 3. Process for the Adaptation Strategies Identification, Pre-feasibility Assessment and Prioritization

Policy Exercise Approach (Policy Option Analysis): The last stage of the methodology is based on different steps to analyze different adaptation strategies. While the DPSIR identifies root causes of environmental problems that can be directly related to the vulnerability of coastal areas to SLR, the policy options are suggested to address those roots causes. The strategies are grouped according to the subject they cover, for instance, technology, knowledge, economics, governance or demographics, among others. After establishing a clear definition for each group, the policy option analysis is carried out considering the following criteria for each alternative: effectiveness, efficiency, equity, political feasibility and implementation capacity (see figure 4). The main strategies are selected by a scoring exercise and analyzed in more detail using the criteria presented in figure 3.

3 During the regional workshop carried out in Cartagena, the stakeholders were asked to identify areas prone to flooding using as a scenario an extreme situation caused by the sum of the high tide and heavy rain that took place in the city in 2003 flooding almost 60 % of its territory. They were also asked to point out the possible effects of such an event.

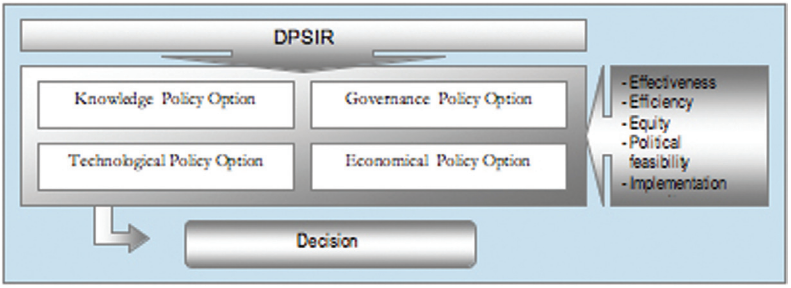


Figure 4. Scheme for the Policy Option Analysis

3. System Description

The Colombian coastal area is highly vulnerable to sea-level rise (SLR). However, the impacts of SLR may differ between the Caribbean and Pacific coasts and vary from one specific case to another. Cartagena de Indias is located on the Caribbean coast and San Andres de Tumaco on the Pacific coast (see figure 5). These areas were identified as critical areas in the first phase of the NCAP because they revealed the highest capital value at risk due to potential SLR. The different impacts that SLR may have on these two areas are explained by the distinct characteristics of each system briefly presented here.

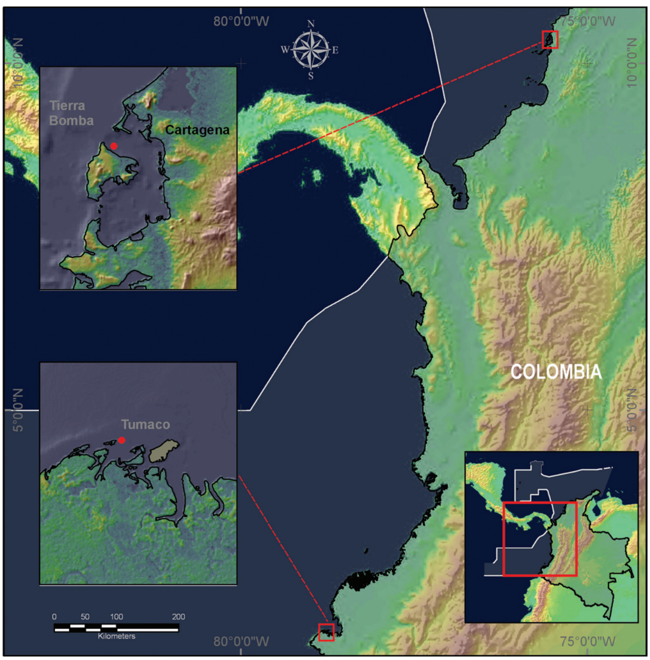


Figure 5. Case Studies: Cartagena de Indias and San Andres de Tumaco

3.1 Cartagena de Indias

The Tourist and Cultural District of Cartagena de Indias, also known as La Heroica, is a large seaport on the north coast of Colombia. Founded in 1533 it was a major center of early Spanish settlement in the Americas, and continues to be an economic hub and, a popular tourist destination.

Cartagena is the capital of the Department of Bolivar that encompasses 44 municipalities covering 6 natural regions. The territorial extension of Cartagena is 609km^2 of which 8.86% belongs to the urban area and 91.15% to the suburban and rural area. According to the National Statistical Administrative Department (DANE), in 2005 Cartagena had 1,030,149 inhabitants with 92% living in urban areas. Approximately 90% of the population of the Cartagena is located in Cartagena Bay.

The population of Cartagena is facing a transitional stage. The rural population growth rate is decreasing mainly due to population migration to the cities seeking better economic opportunities, and to forced displacements to the urban areas due to violence in the countryside. This dynamic has contributed significantly to urban expansion. According to the Network of Social Solidarity, in 2003 Cartagena received 7,138 displaced families due to armed conflict. This equals 31,136 people representing 2% of the total population displaced in Colombia. Generally, the displaced families settle in suburban areas which have had no prior urban planning. Statistics on land tenure indicate that 60% of the settlers are involved in illegal land occupation. The Nelson Mandela District, with the highest concentration of displaced families, has developed without any urban planning. Consequently, the area has poor living conditions and lacks basic amenities such as social and public services. This situation generates environmental problems and is a source of risks for Cartagena's inhabitants.

According to the SISBEN[4], since 2001 the number of people living in poverty and inequitable conditions has increased, reaching 54% of the population of Cartagena by 2003. The results of the SISBEN for education show that only 37% of the population living in poverty conditions graduates from high school, 39% only completes primary school and 22% does not have any education level at all. Despite this situation, since 2000 basic education coverage has been growing. By 2003 Cartagena reached 84% education coverage of basic education. Also, in 2003 Cartagena had 1,360 beds (public and private) available to support the health care demand of 978,000 inhabitants. That indicates a ratio of 1 bed per 720 inhabitants.

Among Cartagena's main economic activities are the commercial and artisan fisheries, trade, industry and tourism. The port of Cartagena exports 14% of the total tons of fish exported by the four main ports of Colombia, and imports 10% of the total tons that enter the country. In general, the trade balance shows an increasing tendency in tonnage handled over time due to the growth of exports and the stable behavior of imports. According to DANE, in 2003 about 34% of the employed population was working in the trade sector. In addition to trade, industry also represents an important economic activity in Cartagena. Industries located in Cartagena are characterized by a high capital/labor ratio, which restricts employment opportunities in the sector. While industrial employment makes up approximately 4% of the total employment in the city, the industrial production of Cartagena represents 6.38% of the industrial national GDP and 98% of the industrial production in the Department of Bolivar.

Weather conditions in the research area are characterized by low rainfall and mostly sunshine. Cartagena's temperature ranges from an average high of 31°C to an average low of 24°C throughout the year. The average humidity in this area is approximately 90% with a wet season that extends from May to September with higher humidity in October, and a dry season from January to April. Cartagena receives about 100cm of rain a year and the rainfall average per month is 90mm. About 30km southeast of Cartagena there is a complex of islands, peninsulas and inner water bodies that form the insular and continental areas. Within the insular area, the national protected parks Corales del Rosario and San Bernardo represent the largest protected marine area of Colombia. The principal inner water bodies within the continental area are Cartagena Bay, the Ciénaga de la Virgen and the Ciénaga de Juan Polo, all connected by a complex system of lakes and channels.

4 SISBEN (System for the Selection of Beneficiaries of Social Programs) is an index widely used by the system of social programs in Colombia. The SISBEN index is a function of a set of household variables related to the consumption of durable goods, human capital endowment and current income.

Cartagena Bay has an area of 82.6km^2 with an average depth of 16m and a maximum depth of 30m. It is connected with the Caribbean Sea through several channels. In the north, the opening between Tierrabomba Island and Lake Bocagrande has a 2km wide jetty located 0.6 to 2.1m deep. In the south, there are three channels: Bocachica, the current sailing channel, 30m deep and 500m wide; the Shipyard channel, 2m deep and 500m wide; and the channel between the islands of Draga and Abanico, 2m deep and 300m wide. The Channel of the Dike is located in the south of the bay. This channel was constructed in 1650 to connect the Magdalena River with the Cartagena and Barbacoa Bays. The Channel of the Dike is about 100m wide and between 2 and 3m deep and has a flow between 100 and 1,100m^3/s. Cartagena Bay is classified as an estuary due to the presence of the Channel of the Dike. In general, the saline stratification is the main factor that influences the dynamics of the bay, formed by the flow of water from the channel, the winds and the tide.

The waves that most frequently hit the coast of Cartagena Bay are produced by the wind coming from the northeast[5]. The average height of these waves is 0.25m. The average height of the waves produced by the wind coming from the west is 0.5m. The marine currents in Cartagena Bay are about 0.05m/s and travel parallel to the coast until Bocagrande. In Bocagrande the currents are stronger reaching 0.10m/s, causing erosion of the coastline. The coastal area of Cartagena is influenced by a semidiurnal tide regime. There are two high tides and two low tides every 24 hours. The range between these is very short (max. 60cm) which categorizes the tide regime as micro-tide. The sea-level in Cartagena is usually low at the end of April and increases during the wet season reaching its maximum level in October. This annual variation is around 40cm without considering the tide. Added to a high tide, this variation can produce an increase of almost 1m in the mean sea-level of the bay during daylight hours in October. This phenomenon causes the well-known annual floods of the low zones of Cartagena, overflowing pipes and opening the bar of the Ciénaga de la Virgen. Among the major disasters experienced in Cartagena during the 1990s, all have been related to atmospheric conditions. A total of 17 disasters were caused by the above discussed SLR.

Cartagena's coastal morphology is characterized by a deficit of sediments resulting in erosion of the coastline[6]. This erosion process was induced by the jetty of Bocas de Cenizas built in 1936, causing the deposit of the Magdalena river's sediments in a submarine canyon located in front of Barranquilla. The jetty is also a barrier to the natural coastal sediment transport between the Guajira and Cartagena. As a result, Cartagena has the problem of a deficit of sediments and erosion of the coastline[7]. The evident coastal erosion and the interest to conserve the area's historical and cultural patrimony motivated local decision-makers to implement protection measures some decades ago. However, the engineering work carried out has been developed without any specific plan and without any assessment of the potential impacts.

With regards to land use, 42% of the study area has no apparent use and is covered with natural vegetation, 14.3% is covered by an urban zone of mixed use, 12.3% by commerce, and 14% by agriculture. Cartagena Bay is completely surrounded by urban areas, except for small areas located in the south of Pasacaballos and Membrillal. The port and industrial activities are located on the east margin of the bay. This area is used for residual water disposal. Since the 1950s, residual water coming from the port and industrial activities has been dumped into the bay without any treatment, along with 40% of the city's sewage water.

As a result of human activities and settlements, the ecosystems in Cartagena show different levels of degradation. In general, and particularly in the north and in the Ciénaga de Tesca, the ecosys-

5 Waves' direction calculated using the software "OLAS" (developed by the CCCP with support from GIOC Spain).

6 Sediment transport calculated applying the methodology of Cerc and Kamphuis, using adjusted parameters proposed by Shoones and Theron (1994, 1996).

7 Throughout the last 12 years the coastal line between Galerazamba and Bahia de Barbacoas displayed important changes associated with coastal processes. This part of the coast is dominated by unconsolidated sediments and low topography. Erosion and sedimentation rates of 10m/year are considered extremely high in comparison to the global standard; nevertheless, in some sectors of Bocacanoas and Flecha de Galerazamba this rate can be as high as 18 and 53m/year. The regional accumulation and erosion processes can be associated with the Galerazamba arcillious diapirism.

tems have been highly affected by extractive processes and unsustainable practices. The ecosystems in Cartagena include coral reefs, sea grass beds, mangroves, coastal lagoons, and beaches. Among them, coral reefs are the most visible and well studied. The most affected are sandy beaches and sea grass beds. Beach ecosystems are equivalent to 90% of the coastal profile of Cartagena. The main impacts on this ecosystem come from human activities over the past decade and erosion due to the strong winds coming from the north[8]. Sea grass beds have also been seriously affected in Cartagena. Only 134ha of sea grass beds can currently be found in the area including seaweed, mollusks, crabs, sponges and sea urchins. Sea grasses are threatened mainly by the untreated sewage disposal and the continental water inflow. Mangrove ecosystems have also been heavily exploited in an unsustainable manner despite the services and resources they provide. It is possible to observe small relicts of mangroves surrounding the islands facing the industrial zone (Mamonal), on the borders of inner streams connected to the Ciénaga de la Virgen and on the borders of Tierra Bomba and Baru Islands. Mangroves also grow in some areas of the Channel of the Dike.

The largest coastal lagoon in the area is the Ciénaga de la Virgen. It is separated from the sea by La Boquilla's bar and is surrounded by mangrove areas and human settlement. Additionally, it is gradually losing area due to the constant inflow of sediments that result from the continental erosion. Sedimentation processes have favored urban expansion towards the inner part of the lagoon. On the eastern flank it receives streams that carry water coming from nearby human settlements, farming and cattle areas. South and west flanks are occupied by human settlements and the construction of a new road along its border. In this area waste water drains from some of the most densely populated areas of Cartagena. The western flank is constantly under pressure from the population of La Boquilla where settlements are constantly growing and causing erosion. Juan Polo's marsh is in the northern part of the Ciénaga de la Virgen. This area is well preserved and is the most influenced by the ocean dynamics within the complex. The central part of the Ciénaga de La Virgen complex shows an island formation, caused by sediment deposition, where mangroves are growing. In general, the environmental degradation in the Ciénaga de la Virgen has affected all the productive activities, especially fisheries, aquaculture and small-scale agriculture.

3.2 San Andres de Tumaco

The Colombian Pacific basin is nearly 80,000km^2 and is located in the western region of the country. San Andres de Tumaco is the second largest city of the Colombian Pacific coast and covers three small islands at the south end of Tumaco Bay: The Viciosa, Tumaco and El Morro.

According to the 2005 census, the municipality of Tumaco had 161,490 inhabitants, 56% living in the urban zone, 36% in the urban peripheries and 10% in the rural areas. Urbanization in Tumaco has increased over time with a 6% increase between 1993 and 2005. Population dynamics are difficult to predict in this area due to migration patterns that are influenced by economic and social factors such as drug trafficking, displacements, the supply of public services and others (Tumaco Municipal Development Plan 2002 - 2004). The population in Tumaco is comprised of different ethnic groups: 92% have black origin, 6% have mixed origin and 2% are native. The population density in the area is 38.3 hab/km^2.

In 2005, almost 50% of the population in Tumaco had unsatisfied basic needs (NBI). 24.1% of the people in Tumaco and 17.6% of the households in the area are in conditions of misery. The SISBEN classification indicates that 62% of the total population was living in conditions of extreme poverty in 2004. In that year, 76% of the population living in the urban area was registered in the SISBEN, as well as 50% of the population living in the rural area.

The level of illiteracy in Tumaco is around 24.6%. Generally, the education in Tumaco is highly

8 The impact caused by erosion processes in these areas is mitigated by sediment deposition during the wet season.

deficient. The low education quality is reflected in the tests of the Colombian Institute for Higher Education Promotion (ICFES) carried out in the area showing results below the national average. Among the main problems of the education sector in Tumaco are poor planning, and deficient quality and coverage. With regards to public health, the rural sector in Tumaco has 17 health centers that work with different limitations. Among these limitations are the lack of administration capacity, low coverage, deficient attention capacity and equipment, and difficult access to the service.

Concerning basic household services, both the drinking water distribution network and the sewage system in Tumaco are deficient. The water system is over 30 years old and the maintenance is of bad quality. Moreover, more than 35% of the urban population and over 90% of the rural population lacks this service. As a result, the population mainly consumes water from rivers without proper treatment. The sewage system is highly deficient. It covers only 5% of the houses located in the districts of Pradomar, La Florida, Miramar and La Ciudadela. While some of the population disposes of residual waters into septic wells, 90% deposit it directly into the sea without any type of treatment causing contamination problems in the area.

The main economic activities in Tumaco are agro-industry, fishing and shrimp cultivation. The production supplies both domestic and international demand. The physical characteristics and geographical location of the port in Tumaco makes it a convenient port for oil export. Therefore, Tumaco's main export is palm oil. In 2004, the port registered foreign trade of 39,336,840 tons. Despite not recording imports, the trade displayed a growth of 14% compared to 2003. In the rural area, the main activities for men over 10 years old are agriculture and fishing, while for women the main activity is house labor and mollusk fishing. Generally, agriculture is the main generator of labor in the area, where palm oil plantations provide employment to 4,000 people.

The temperature in Tumaco ranges from an average high of 33°C to an average low of 18°C. Rainfall is constant throughout the year (annual mean 250cm), with heavy rainfall in the months of April, May, June and January and less rainfall in the months of February, October and November. The humidity is relatively high, with measures that lie between 80 and 88%, reaching 100% at night.

Tumaco has rich water resources due to high rainfall and rivers that come from the 5 basins that form Tumaco's inlet. Rio Rosario has influence over 60% of Tumaco's inlet and is formed by four sub-basins: Caunapi, Alto Rosario, Bajo Rosario and Mejicano. Rio Rosario and Mejicano drain directly into the sea and run through 25.2% of Tumaco's territory.

The coastal zone of Tumaco is divided in three zones: a low belt, a flat area and a high area. The 3 to 5km wide low belt is affected by tides. The tide regime in Tumaco is semidiurnal with two high tides and two low tides every 24 hours. The average for high tides is 2.807m and 0.294m for low tides. The mid range is 2.513m and the average SLR is 1.530m. The inter-tidal zone is divided into inter-tidal platforms without vegetation cover and floodable platforms with vegetation cover. The first areas are where sediments cluster and are completely covered with water during high tides. The second areas are periodically flooded by tide action. They are covered mainly with mangroves and ferns, and other vegetation that can stand halophytic conditions. These areas can also receive sediments from fluvial systems. Adjacent to the low belt described above, is a region that varies from 35 to 45km wide. Bordering this region are higher areas that reach over 500m above sea level.

Most of the beaches in Tumaco are relatively well conserved because they have not faced major human pressures. Beaches in Tumaco can be divided into: 1) ample beaches: over 20m wide, with some vegetation, dunes and littoral cords that are less than 70cm in height; 2) moderate beaches, between 5 and 20m wide; and 3) narrow beaches, less than 5m wide. Locations with potential for tourism in the bay of Tumaco are the beaches of Bocagrande, el Morro Island and the Mira

River. In geomorphologic terms, the coastline of Tumaco has been constantly changing over the past 3 decades. According to the surveys held by the Contamination Control Centre of the Pacific (CCCP) in Tumaco (2002), the changes in morphology are mainly attributable to erosion and sedimentary processes induced by ocean dynamics affecting the area such as high tides and the effects of the "El Niño" event in 1982/83 and 1995/96. To a lesser extent, human activities have also impacted Tumaco's coastline. Activities that had a large impact were the artificial refill of Tumaco Island in the 1960s and the joining of La Visiosa Island with Tumaco in the 1970s.

Tumaco's forest cover represents 60% of the total territory. The ecosystems close to the coastline are formed by tropical rainforests. These rainforests characterized by small temperature variations and high precipitation and humidity, are the most complex ecosystems in terms of structure, stratification and species diversity. Tropical rainforests cover 42% of Tumaco's territory. In general, forests resources in Tumaco are exploited for local use and trade. Some of the species in these forests are recognized as highly threatened due to over-exploitation, fragmentation and contamination, among other reasons. Away from the coastal areas, agricultural systems and cattle ranges are expanding.

In littoral areas the most predominant vegetation is mangroves. The Nariño Department has the largest mangrove cover of the country with a total of 149,735ha. Most mangrove species can be found in Tumaco. Mangrove ecosystems cover 29% of Tumaco's total area (97,400ha) and can especially be found in the Guandarajo estuary, in the Mira river estuary, in some areas between cliffs and recent littoral cords on the southern part of Tumaco Island, and on the beaches of Bocagrande, Cabo Manglares, and Ancon's Bay. In general, mangroves have been affected by human settlements, as well as by unsustainable extraction activities, aquaculture (mainly shrimp farming), and tannin production.

4. Vulnerability Assessment and Scenarios

Determining and reducing vulnerability is a critical part of building adaptive capacity to potential climate change effects such as SLR as it considers present situations and possible future conditions. It is important to consider the results of this assessment in local planning to reduce the associated risks of SLR in the study areas and enhance resilience to current climatic variability and extremes, and consequently to future climate change. The vulnerability assessment includes the evaluation of the natural systems' susceptibility and the socio-economic systems' vulnerability.

4.1 Natural Susceptibility Assessment

Using the results of the first regional workshop and available information, the natural susceptibility assessment is estimated based on the indicators described in annex 3. These indicators are computed to obtain the overall natural susceptibility index (annex 1) for each area.

4.1.1 Cartagena de Indias

The natural susceptibility of the study area in Cartagena – formed by Cartagena Bay and the Ciénaga de la Virgen – is determined by the following results.

Ecosystem coverage

The Ciénaga de la Virgen and Cartagena Bay have three main types of marine ecosystems: mangroves, sea grasses and beaches. Over the past 20 years, mangroves in these areas have deteriorated as a consequence of wood exploitation and other human-related pressures, resulting in a total loss of 10 to 24% in the Ciénaga de la Virgen and 90% in Cartagena Bay. The susceptibility of these ecosystems to this indicator is considered to be medium-low. Sea grasses are also highly susceptible to changes in the surrounding environment and a loss of over 92% of sea grasses has been calculated for the entire area. As a result, this indicator defines this ecosystem as highly susceptible. Beaches experience a constant loss and gain of area due to climate variability and ocean dynamics, resulting in erosion and accretion in some areas. Beaches that experience highly erosive processes and are therefore highly susceptible are located in the areas of Castillo Grande, Bocagrande, El Laguito and Tierrabomba.

Water quality and hydrographic processes integrity

The result is not as negative as expected despite the fact that that water bodies are used as receptors of untreated waste in Cartagena. The values obtained show that water quality is not a hazard for associated flora and fauna, indicating medium-low susceptibility.

Ecosystem quality

Unplanned urban and industrial development in the Ciénaga de la Virgen and Cartagena Bay has resulted in a lack of sewage treatment that has deteriorated the ecosystem quality in these areas. Additionally, waste accumulation and infrastructure have interrupted water exchange between the Ciénaga de la Virgen and the sea, resulting in further degradation. The ecosystems in Cartagena Bay are also affected by the fuel and oil coming from the port. This has resulted in associated macrofauna loss and high contamination levels. In general, sea grasses are threatened by fragmentation and are highly susceptible. Mangroves are also fragmented and suffer from different types of human-induced pressures. As a result, this ecosystem's quality has a medium level of susceptibility.

Recovery areas

Studies carried out to evaluate the system's state in Cartagena have identified the need to protect and recover some areas. CARDIQUE proposes a system of protected areas for mangroves in Cartagena Bay and in the Ciénaga de la Virgen. Considering that protective measures for mangroves are intended, but are not in place yet, this ecosystem has a medium-high level of susceptibility to this indicator. The protection of sea grasses on the other hand, is not supported by any regulation; therefore, this system is highly susceptible.

Land use: habitat conversion

Cartagena Bay is occupied by urban and industrial areas. Industry has a significant impact on the ecosystem due to the constant disposal of wastes and fuels into the bay. Fishing activities and wood exploitation also take place where mangroves are still present. The main factors threatening mangroves are housing construction (urbanization) and agricultural expansion. As a result, this indicator values this ecosystem in a medium-high level of susceptibility. The beaches also have a medium-high level of susceptibility because they are invaded and altered by new building construction.

The land use in the Ciénaga de la Virgen area is characterized by settlements of people living in poverty conditions. In general, people in this area exert significant pressure on the ecosystems. The land in this area is mainly used for urbanization, agriculture, fishing, and aquaculture. Flooded areas where mangroves used to grow have been colonized, deforested and filled out with different materials to make them suitable for building construction. This process has taken place without planning, resulting in a complete lack of basic infrastructure for public services and waste disposal. This area also receives an inflow of untreated wastes from other areas of the city with an estimated volume of 15 tons of organic matter per day. Additionally, urbanization and agroindustrial activities affect the natural water exchange with the sea and produce agrochemical waste that affects the natural system.

Hazards[9]

The climate hazards for this area are: liquation, soil erosion and flooding risks. Based on the information analyzed, these are not considered to be severe for the natural system (medium susceptibility).

9 This evaluation combines the information provided by risk maps for different areas in Cartagena, and expert knowledge that helps to determine the impacts that such hazards may have on the natural system.

The ecosystems in Cartagena face several pressures that make them highly vulnerable, diminishing their capacity to cope with the effects of climate change. The overall susceptibility for sea grasses is high, for mangroves is medium and for beaches it varies from low to high depending on the location. Sea grasses face constant hazards that have resulted in an almost total loss of its coverage area. Given the degradation of this ecosystem and the lack of measures to reduce the pressures affecting it, its recovering capacity is highly susceptible. Among the mangroves in Cartagena, the most threatened are the ones located in the urban areas of Tierra Bombas and the Ciénaga de la Virgen. These mangroves face tremendous pressure as a result of urbanization and human activities. Nevertheless, it is important to consider that efforts to recuperate and regulate the use of mangroves in Cartagena are intended. For beaches, erosion and building expansion are the main pressures affecting their susceptibility making them highly susceptible in some areas of Cartagena.

In general, the ecosystems' qualities are degraded by unsustainable use and land use conversion processes, and to a lesser extent by water quality and hydrographic processes. Fragmented ecosystems are the most susceptible natural systems in Cartagena. In the study area, natural systems' susceptibility is directly related to human presence: high susceptibility is mainly the result of the impacts caused by human activities and settlements.

4.1.2 San Andres de Tumaco

The natural susceptibility of Tumaco is determined by the results presented below. The focus is placed mainly on mangroves since there is no available information to evaluate the susceptibility of beaches for all the indicators.

Ecosystem Coverage[10]

Mangroves in Tumaco present a medium-high to high level of susceptibility for this indicator. These ecosystems are deteriorated mainly as a result of pressure exerted on them by local communities that use them as a source of fuel and wood. In some areas, the impacts are caused by agriculture expansion (mainly coconut plantations) and urbanization, as well as by human activities and settlements.

Water quality and hydrographic processes integrity

Water quality data obtained by INVEMAR's marine quality network (2001 to 2004), does not exhibit threatening values, despite the fact that water bodies in this area are used as receptors of untreated waste, due to a lack of sanitary services and appropriate waste disposal. The values obtained show that water quality has a medium-low level of susceptibility and is not the main hazard for associated flora and fauna in the area.

Ecosystem quality[11]

In general, the ecosystem quality of Tumaco's mangroves is not considered to be in a critical state. However, the mangroves located in the most populated area of Tumaco are highly susceptible. In this area, the main threats to mangroves are extraction and unplanned urban development (without a proper sewage treatment). Moreover, major causes of pollution are the occasional hydrocarbon spills that occur in the area which have a large impact on mangroves and associated fauna.

Recovery areas

In the most populated area of Tumaco, natural recovery processes are very unlikely to occur leading to a permanent loss of mangrove areas. No protective measures have been taken by the government in Tumaco to protect mangroves. Despite this, some areas are naturally recovering from highly destructive processes that took place in the 1960s and 1970s as a result of tannin extraction. These recovering areas, however, are small compared to areas that are currently being

10 Information used to calculate this indicator for Tumaco's mangroves represents just one time period (1997), as this was the only information available.

11 This indicator combines mangrove area loss, associated representative parameters and Holdridge's complexity index.

degraded. As a result, Tumaco's mangroves are considered highly susceptible systems to climate change effects.

Land use: habitat conversion
Tumaco is occupied by agricultural and human settlements. Densely populated areas present greater land conversion processes resulting from urbanization. In these areas mangroves are used as fuel and wood. Other areas are being converted into agricultural areas and to a lesser extent to aquacultural areas mainly to develop shrimp pools. These activities put tremendous pressure on mangroves, particularly because recovery processes are very slow. Regulations to restrict and guide the sustainable use of natural resources do not exist in Tumaco. Therefore, the susceptibility level of mangroves is high for this indicator.

Hazards
Tumaco's mangroves and beaches have a medium level of susceptibility to important climate hazards such as tsunamis, erosion, and flooding.

Mangrove ecosystems in Tumaco face major pressures that make them susceptible, diminishing their capacity to adapt to potential impacts caused by climatic events. The lack of local measures and planned management to conserve these ecosystems make degradation processes that affect their susceptibility more difficult to control. This situation is particularly alarming close to Tumaco's urban area, where mangrove ecosystems face pressures from urbanization, direct exploitation and generally low environmental quality due to waste water disposal in the area. In general terms, it is estimated that mangroves have a medium level of overall susceptibility. For beach ecosystems, the lack of available information complicated their susceptibility assessment in Tumaco. Nonetheless, considering that the daily tide variation contributes towards building the response capacity of these ecosystems, the overall susceptibility of beaches is estimated at medium-low to medium level.

4.2 Socio-economic Vulnerability Assessment

Socio-economic vulnerability is based on the technical, institutional, economic and cultural ability of society to cope with or prevent impacts to the socio-economic system. Socio-economic vulnerability is influenced by the susceptibility of ecosystems and vice versa. It is also influenced by the infrastructure, location, living conditions, governance and social dynamics that define the level of empowerment and access to resources that determine the range of viable options to react to difficult situations. Socio-economic vulnerability is estimated based on the indicators described in annex 4. These indicators are computed to obtain the overall socio-economic vulnerability index (annex 2) for each area.

4.2.1 Cartagena de Indias
The socio-economic vulnerability of Cartagena is determined by the results obtained for each indicator presented in Table 4.

According to stakeholders' perceptions, the sewage system is not able to cope with the city's annual flood due to deficient maintenance. This indicator shows that 23% of the urban area and 50% of the rural area have a medium level of vulnerability.

The overall socio-economic vulnerability of the urban area in Cartagena is estimated at medium to medium-high level. Neighborhoods located on the southern border of the Ciénaga de la Virgen exhibit high socio-economic vulnerability. The north-western urban area and neighborhoods along Santander Avenue exhibit high and very high vulnerability levels. The neighborhoods close to Chambacu and San Lorenzo lagoons exhibit high and medium-high vulnerability. Finally, the southern area of Tierra Bomba presents medium and medium-high level of vulnerability.

Table 4. Vulnerability of Cartagenas's Socio-economic System

Life quality	According to stakeholders' perceptions, the sewage system is not able to cope with the city's annual flood due to deficient maintenance. This indicator shows that 23% of the urban area and 50% of the rural area have a medium level of vulnerability.
Services	Approximately 50% of Cartagena's rural area has high vulnerability and about 40% very high. However, 66.5% of the urban area has medium-low vulnerability.
Housing	While 40% of the rural area in Cartagena has medium-low vulnerability, 72% of the urban area has low vulnerability.
Human capital factor	Both urban (36%) and rural (43%) areas have a medium-high level of vulnerability, denoting the deficient coverage of basic education in Cartagena. Access to education in the rural area is particularly difficult.
Natural disasters	Both urban (84%) and rural (73%) areas exhibit low vulnerability. This means that most of Cartagena's population feels safe in the place where their houses are located.
Public investment	In general terms, Cartagena has low vulnerability regarding public investment.
Population indicators	The total study area (97% of the rural area and 95.5% of the urban area) exhibits very high vulnerability.

The overall socio-economic vulnerability of the rural area of Cartagena is estimated at a medium to medium-high level. According to the assessment, the population located in the rural area of the Ciénaga de la Virgen presents an overall medium-high socio-economic vulnerability. A similar situation occurs with the population close to La Boquilla. In these areas mainly firewood is used to cook and sanitary services are deficient.

4.2.2 San Andres de Tumaco

The socio-economic vulnerability of Tumaco is determined by the results presented in table 5.

Although the results show significant differences in life conditions between the urban and rural areas, the overall socio-economic vulnerability for both is estimated at medium-high to high level. In the Tumaco and Visiosa Islands over half of the secure areas have high vulnerability. Also, Miramar urbanization presents very high vulnerability to SLR. On the Island of El Morro, most of the secure areas show a medium-high level of vulnerability, while the secure areas of the continental area of Tumaco have a high level vulnerability to SLR. Concerning the rural coastal area of Tumaco, 48.4% of the area exhibits a high level of vulnerability and 22.6% a medium-high level of vulnerability.

Table 5. Vulnerability of Tumaco's Socio-economic System

Life quality	The three secure areas* of Tumaco's urban area, present medium-high vulnerability. On the other hand, 80.6% of the rural coastal area has high vulnerability and 19.4% very high vulnerability.
Services	This indicator estimates a medium vulnerability for the 3 secure urban areas of Tumaco. In the rural area, 32.3% of the houses exhibit very high vulnerability and 48.4% high vulnerability.
Housing	The housing in Tumaco's urban area shows a medium level of vulnerability. However there are neighborhoods in each of the 3 secure urban with high vulnerability, such as Luis Avelino Pérez on the Island of Tumaco, Pradomar on the Island El Morro and Ciudadela in the continental area. In the rural area, 93% presents a medium-high level of vulnerability for the housing indicator.
Human capital factor**	In general, Tumaco's urban area exhibits a low vulnerability with respect to the human capital factor, except for el Pindo and Ciudadela which have medium-low vulnerability. In contrast, the entire rural area has a very high vulnerability.
Natural disasters	Although the classification of the urban area corresponds to the secure areas, the public perception of the location of houses in risk areas exhibits medium-high vulnerability for Tumaco's island and La Viciosa. Continental areas present medium-level of vulnerability and el Morro Island a medium-low level. A large part of the coastal rural area (45%) shows very high vulnerability.
Public investment	Given that Tumaco applies the Broke Law (*Ley de Quiebra*), investment resources are low as they are redirected to pay public debt. As a result, no investment is made in disaster prevention and housing, two of the variables with the heaviest weighting in this indicator. Consequently, the urban and rural areas have a very high vulnerability.
Population indicators	Both the rural and urban areas exhibit a very high level of vulnerability, except for Chajal which shows a high level of vulnerability.

* The secure areas of Tumaco are areas that have been identified as safe in case of natural events such as tsunamis. Three of these areas located in the urban area have been selected for the study to demonstrate that a potential SLR may affect even the most secure areas.
** To analyze the human capital factor, the Sisben is used.

4.3 Scenarios under the 2019 Vision

The scenarios described hereafter do not assume to predict what will happen, but are merely descriptions of different possibilities the study areas may face according to their present situation and the way local governments are planning their future development. Scenarios are placed in the year 2019, when the National Vision is to be fulfilled by the present administration.

From the socio-economic point of view, the national vision expects an annual economic growth rate of 6% and a significant improvement in the quality of life of the population. It envisages a 100% urban coverage of both water supply and sewage treatment (compared to a current 97.4% and 90.2% respectively) and a rural coverage of 82.2% for water supply (compared to 68.6%) and of 75.2% for sewage treatment (compared to a current 57.9%). Moreover, 100% coverage in basic education and 40% in higher education (the current rate is 25.7%) is planned. Furthermore, by 2019, Colombia plans to integrate its marine area (44.8% of the total territory extension) into the country's development strategy, enhancing the growth of potential productive sectors such as tourism (by eight times) and bio-trade.

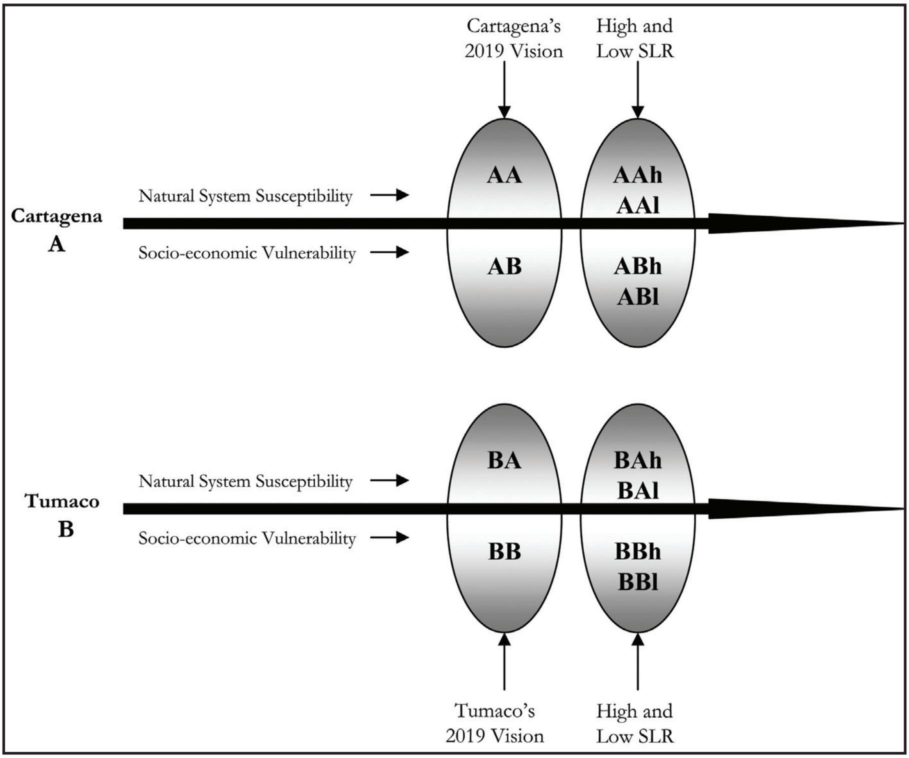
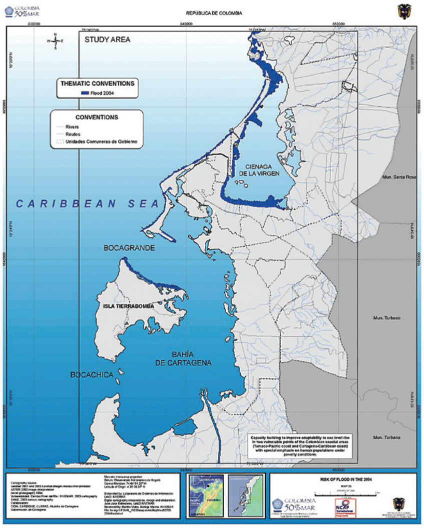


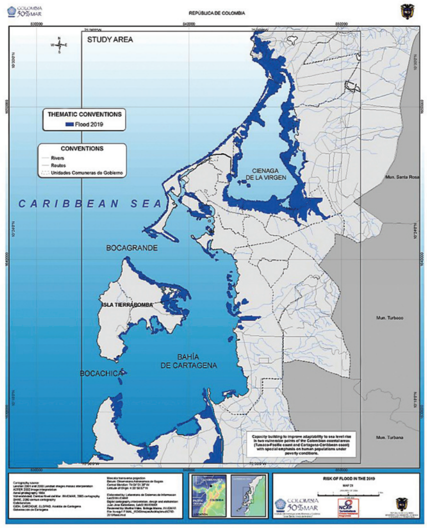
Figure 6. 2019 Scenarios Development Framework

On the subject of the environment, Colombia's vision for 2019 implies a development based on the sustainable use of natural resources involving society in the different decisions to be taken on environmental matters and on the analysis of costs and benefits of development strategies. The need to integrate environmental considerations into all development planning is recognized. As a direct result, the national vision aims for a reduction of environmental impacts and pressures causing biodiversity loss and ecosystem degradation. It also aims for an increase in the adoption of prevention and mitigation measures in the country.

The following scenarios (see figure 6) are developed with the objective to foresee the effects that a change in the socio-economic variables (bought about by the achievement of the Colombian Vision 2019 objectives) may have on the natural systems' susceptibility and socio-economic vulnerability of the study areas.

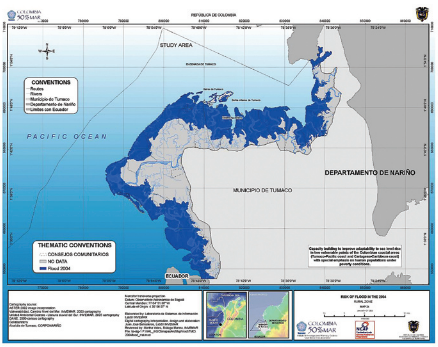


Low SLR

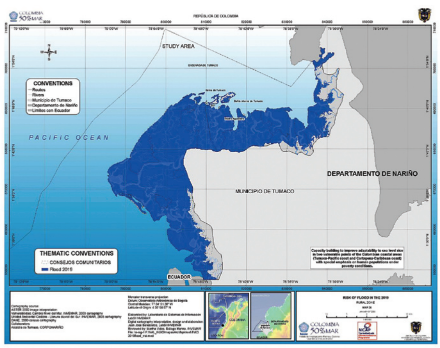


High SLR

Figure 7. Cartagena de Indias SLR Levels for 2019 Scenario Development



Low SLR



High SLR

Figure 8. San Andres de Tumaco SLR Levels for 2019 Scenario Development

Box 3. Cartagena's Vision for the Environment

Cartagena's vision for the future is of a developed city, exploiting its potential in a sustainable manner, positioned highly in the tourism sector both nationally and internationally. According to the Territorial Organization Plan (POT), Territorial Environmental Management Plan (PGAT), and the Colombian 2019 Vision, Cartagena will integrate environmental considerations into its territorial policies and planning. This means introducing measures to ensure the protection and sustainable use of its natural systems, as well as improving the quality of life of the populations that depend directly or indirectly on these systems.

Thereafter, different SLR levels are added to the scenarios to assess the possible impacts these may cause on the systems (see figure 6). Two SLR levels are considered: low and high. The high levels used for the 2019 scenario development are based on severe flooding scenarios that the study areas faced in the past (see figures 7 and 8). This was useful, because stakeholders could relate to past events to recognize the impacts of SLR and on this basis propose adaptation measures.

4.3.1 Scenarios for Cartagena's 2019 Vision

AA: Effects on Cartagena's Natural Susceptibility

Despite population and industry growth, the integration of environmental considerations into the development strategies of Cartagena will allow for maintaining and at times reducing the susceptibility of natural systems in this area. Water quality and the integrity of hydrographic processes may improve as proper waste disposal and sewage treatment systems are introduced. This action reduces the pressures placed on mangroves in Cartagena Bay, thus improving the ecosystem's quality. Despite this, mangroves in the northern area of the Ciénaga de la Virgen will disappear as a result of drainage from urban expansion. The combination of the different indicators calculated for the 2019 scenario show that the overall susceptibility in Cartagena will maintain the current levels: mangroves medium level, sea grasses high level and beaches medium to high level of susceptibility.

Scenarios AAl and AAh: SLR Impacts on the Susceptibility of Cartagena's Natural System

Adding to this scenario the effects of a potential low and high SLR, it is possible to see that the areas with higher susceptibility indexes are the more affected ones. In general, a low level of SLR exacerbates erosion processes on beaches impacting natural communities, resources, and services provided by this ecosystem. Mangroves on the other hand, tend to disappear given the absence of available areas for migration mainly due to physical barriers. It is estimated that a low SLR will flood 17.5km^2 of beach and 2.23km^2 of mangrove areas. A high level of SLR will cause the same effects but in a larger magnitude, flooding 18.6km^2 of beach and 13.3km^2 of mangrove areas.

The most affected mangrove areas appear to be the ones closer to human settlements. Although mangroves are crucial in reducing erosion processes and could serve as buffer zones to climatic events protecting the human settlements located nearby, these ecosystems will tend to disappear given the lack of space to migrate in these areas. With this in mind, it is important to find measures to preserve these systems and implement strategies that will help mangroves adapt to SLR.

An SLR will cause the disappearance of almost all the beaches in Cartagena Bay and in Tierra Bomba. Beaches play a very important role for the tourism industry in Cartagena and serve as a protective zone for the infrastructure located nearby. As such, a significant loss of beaches could have serious impacts on the city's socio-economic development. The next section further explores the impacts that SLR could have on the socio-economic system developed under the 2019 Vision.

Scenario AB: Effects on Cartagena's Socio-economic Vulnerability

Box 4. Cartagena's Vision of Socio-economic Development
The national government's goals for 2019 include the improvement of housing in the urban zone, the development of "social" housing in the urban and rural areas, and the relocation of houses in high risk areas. Among other things, Cartagena envisions a constant population growth; 100% water supply coverage in urban areas and 82.2% in rural areas; 100% coverage in waste collection services; and 100% education coverage in rural and urban areas. The risk perception regarding housing location will diminish by 80% and the gap between the rural and urban areas' living conditions will notably reduce.

The achievement of the socio-economic goals established under the Cartagena's 2019 Vision contributes towards reducing the overall socio-economic vulnerability of the area from a medium-high to a medium-low level. Table 6 presents the vulnerability changes for each socio-economic indicator.

Table 6. Socio-economic Vulnerability of Cartagena's 2019 Vision

	Vulnerability		
Indicator	**Present**	**2019 Vision**	**Comment**
Life quality	medium- low	low	Full coverage of basic services in urban areas and over 80% in rural areas will reduce the quality of life gap between urban and rural populations
Services	U: high R: medium- low	low	100% coverage of basic services in urban areas and over 80% in rural areas
Housing	U: low R: medium- low	low	Changes in the materials used for building houses in the rural and urban areas
Human capital	medium- high	medium- low	Although a cover of 100% in basic education is intended, maximum score is not obtained
Natural disaster	low	low	Relocation of the houses that were in risk areas
Public investment	low	low	Financial situation of Cartagena can increase social investment to 90%; 15% in disaster prevention
Population	very high	very high	Constant growth rate

Note: U: Urban; R: Rural

Scenarios ABh and ABl: SLR Impacts on the Vulnerability of Cartagena's Socio-economic System

The effects of a potential SLR could seriously impact Cartagena's economy, cultural heritage and the quality of life for the population. A potential SLR could impact the local economy by 1) flooding the beaches that are an important asset for tourism; 2) flooding the road that connects Cartagena with Barranquilla and the interior of the country, isolating the city from a large portion of Colombia; 3) flooding the Perimetral road around the Ciénaga de la Virgen affecting the population located in this area; and 4) flooding the facilities of the ports and interrupting their operations. Moreover, an SLR could also have negative impacts on the cultural heritage of the city by affecting the historical walls and monuments causing a possible collapse of these structures. Lastly, by impacting Cartagena's natural systems, an SLR could affect the quality of life of the population. For instance, a rise in the sea-level could cause penetration of the salt wedge into the Juan Gomez marsh considered the city's main source of water for human consumption. This would significantly affect the water supply for Cartagena's population. Finally, flood and erosion processes caused by SLR could also directly affect human settlements causing population displacement and relocation. This is particularly the case with settlements located on Tierra Bomba Island.

To estimate the socio-economic impacts of SLR, value at risk (in pesos) is calculated using two levels of SLR and the 2019 socio-economic scenario (see table 7). In general, the value at risk in high vulnerable areas increases due to an improvement of the socio-economic factors. Affected population was calculated using a constant population growth. In terms of population, the area most affected by SLR under Cartagena's 2019 Vision will be the south of the Ciénaga de la Virgen.

Table 7. Socio-economic Impact of SLR on Cartagena's 2019 Scenarios (value at risk in millions of pesos)[12]

Area	Low SLR	High SLR		
	Value at loss	Affected population	Value at loss	Affected population
Urban	654,127	58,956	872,226	303,891
Rural	NI	1,749	NI	4,667
Total	654,127	60,705	872,226	308,558

Note: NI: No Information

4.3.1 Scenarios for Tumaco's 2019 Vision

Scenario BA: Effects on Tumaco's Natural Susceptibility

Box 5. Tumaco's Vision for the Environment

To reach its 2019 Vision objectives, Tumaco has planned different strategies. One of these strategies emphasizes environmental education with the goal of creating commitment and understanding among the community of their responsibility towards the sustainable development of the area. Aimed at generating environmental awareness among the population, Tumaco foresees a reduction of the pressures exerted by human activities on the natural systems. In this sense, environmental quality will improve not only as a result of institutional action, but also due to a change of behavior in the population. Another strategy that Tumaco is planning includes the promotion, establishment, recovery and implementation of protected areas, either by the state or civil society. Also, Tumaco plans to increase its participation in the green market. To do so, traditional production systems will be promoted, introducing improvements that do not have negative impacts on the environment. In addition, research in science and technology will be enhanced, as well as business development. The combination of these strategies will contribute towards the main objective of Tumaco's 2019 Vision: to guarantee food security for the population without threatening natural systems, promoting sustainable development and strengthening green market programs.

The integration of environmental considerations into the planning process and the adoption of more sustainable production practices under Tumaco's 2019 Vision will reduce the impacts on natural systems generated by population growth and socio-economic development. Ecosystem quality will be enhanced as a result of the establishment of protected areas and the teaching of the

12 Currency conversion for 2002: 1 US$ is equivalent to 2296 Colombian pesos.

Box 6. Tumaco's Vision on the Socio-economic Development

By 2019 Tumaco envisions 70% basic education coverage; 40% reduction in housing deficit; relocation of houses located in risk areas (80% relocated in areas with no associated risks); and improvement of housing (external walls will be made using exclusively wood and bricks). Tumaco also aims to promote electricity and gas for cooking replacing firewood, coal and kerosene. Finally, it also foresees universal coverage of basic services, as well as fiscal sustainability, implying a large investment in health, education, basic services, infrastructure, housing and disaster prevention before 2019.

Table 8. Socio-economic Vulnerability of Tumaco's 2019 Vision

Indicator	Vulnerability		
	Present	2019 Vision	Comment
Life quality	U: medium-high R: high	U: medium- low R: low	Tumaco will achieve a remarkable improvement in quality of life for inhabitants
Services	U: medium R: very high	low	Remarkable improvement in quality of life in the rural area expanding basic services coverage
Housing	U: medium R: medium- high	low	Changes in the materials used for building houses in both the rural and urban areas
Human capital	U: low R: very high	medium- high	Increase to 70% basic education coverage including the rural and urban areas
Natural disaster	U: medium- high / medium R: very high	low	As a result of housing policies and relocation of houses in risk areas, 80% of the population lives in areas with no associated risks, and the remaining 20% in areas with different associated risks
Public investment	very high	medium- low	Investment increase for housing and disaster prevention
Population	very high	very high	This indicator presents no variations. Since the coastal area is the most vulnerable and the most populated, this indicator remains the same.

Note: U: Urban; R: Rural

population about the need to conserve these ecosystems. This means that although total ecosystem coverage might not increase, due mainly to land conversion for urban and agricultural expansion, ecosystem degradation will be reduced due to a more sustainable use of the natural resources and the creation of protected areas.

Moreover, the improvement in waste disposal and sanitary systems and agricultural practices will reduce the pollutants affecting ecosystem quality such as water quality and maintain the integrity of hydrographic processes. Therefore, although population growth may exacerbate domestic and agricultural activities, these activities will not affect the susceptibility of natural ecosystems. The overall susceptibility of Tumaco's natural systems will remain the same, due to the long time that natural systems take to recover and the high influence that human actions have upon them.

Scenarios BAl and BAh: SLR Impacts on the Susceptibility of Tumaco's Natural System

Adding to this scenario the effects of a potential low and high SLR, it is possible to see that given Tumaco's topography and local conditions (tide regime and other oceanic dynamics) both SLR levels will affect the entire area covered by mangroves and beaches. Nevertheless, Tumaco would have enough space to allow for migration of most of these ecosystems if local regulations were implemented to stop the construction of potential barriers. As a result, the overall natural susceptibility of Tumaco is estimated to remain at a medium level for mangroves and beaches.

The threat to mangrove ecosystems remains high given the amount of people present in the area and the unsustainable way they use these ecosystems. However, the loss of beaches will probably be compensated by new accretion processes that will occur, thus complicating the process to determine the effects that SLR can have on these ecosystems.

Scenario BB: Effects on Tumaco's Socio-economic Vulnerability

In general, the socio-economic vulnerability in the rural area of Tumaco decreases from a high to a medium level of vulnerability in 2019. In the urban area all the secure areas exhibit a medium level of vulnerability and also show a decrease compared to the current medium-high level of vulnerability. The overall decrease in socio-economic vulnerability in 2019 indicates an increase in both the rural and urban populations' quality of life compared to the current state. Table 8 portrays the vulnerability changes for each one of the socio-economic indicators in Tumaco.

Scenarios BBh and BBl: SLR Impacts on the Vulnerability of Tumaco's Socio-economic System

If there was only a low SLR, the urban area divides into areas with a medium-level of vulnerability and areas with a medium-low level of vulnerability. The estimations reveal that the islands have lower socio-economic vulnerability to flooding compared to the continental area. This is because the infrastructure of the islands is built considering a potential increase in the sea-level, while in the continental area the infrastructure is built without taking into consideration any preventive measures. In general terms, a medium level of vulnerability is estimated for the urban area in Tumaco. The impacts of a high SLR are similar but larger in magnitude.

Table 9. Population affected by SLR in Tumaco's 2019 Scenarios

Area	Low SLR	High SLR
Urban	33,271	37,172
Rural	8,463	12,988
Total	41,734	50,159

To evaluate the socio-economic impacts of a potential SLR in Tumaco it was not possible to calculate value at risk due to the lack of available information. Table 9 presents the affected population for a high and low SLR scenario assuming a growth rate in line with the development planned under the 2019 Vision. Although the rural area has a larger flooded area, the population most affected by SLR is in the urban area. This is explained by the fact that the urban area in Tumaco is more populated than the rural area.

5. Sea-level Rise Adaptation Measures

Generally, adaptive measures to SLR will fall into one of the following three categories: retreat, accommodate or protect. Retreat typically focuses on planning for relocation and emergency management. It involves preventing development in vulnerable areas or planning development in certain areas under the condition to abandon them if necessary. Accommodation measures are based on the principle of not counteracting the migration process of ecosystems caused by SLR. To do so, functional uses of land are adapted allowing for both migration processes and productive activities to continue. Finally, protection measures involve planning and regulation to protect systems from the effects associated with SLR. It is generally recognized that anticipatory and precautionary measures for adaptation are more effective and less costly than forced, last minute emergency adaptation measures.

Within the categories presented above, adaptation to SLR can be promoted by planning, building physical structures, introducing legislation and/or creating organizational/institutional capacity. Planning is related to the decision-making process and the development of programs that can directly or indirectly integrate adaptation into the management of the study areas. Physical structures refer to engineering work (soft and hard structures, see below) that can be built to protect the areas from the effects of SLR. Legislation refers to the normative framework that can support the implementation of measures to prevent impacts from SLR. Finally, creating organizational/institutional capacity relates to institutional strengthening, education, public information and participation, emergency management capacity and inter-institutional cooperation, among others.

Using a modified checklist and database to evaluate adaptation measures, a list of measures was generated for both Cartagena and Tumaco. An Adaptation Decision Matrix was then used in workshops with local stakeholders to identify suitable measures for both of the study areas. In specific terms, several adaptation measures consisting of the different adaptation categories described above were proposed for each area.

To prevent the impacts of a potential SLR and cope with the effects, the following adaptation measures were locally proposed for Cartagena. Additionally, suggested protection measures for this area are described in box 7.

- Establishment of a new regulation to design and build housing and infrastructure in general that takes into consideration a potential 1m SLR. For instance, hotels have to be designed with consideration that their ground-floor may flood occasionally.
- Development of retreat plans for the population settled on beaches with high erosion level such as La Boquilla.
- Development of an action plan for the protection of shores and roads.
- Viability study for the construction of artificial reefs located parallel to the coast to reduce wave action on the beach.

In San Andres de Tumaco, the adaptation measures identified with local stakeholders considered the following. In addition, proposed protection measures for this area are given in box 7.

- Establishment of a new regulation to design and build housing and infrastructure in general that limits construction below 3.4m above sea level. The area below this height has to be designated for conservation of the natural systems. These natural systems will be buffer zones that will protect the infrastructure from a potential SLR. For instance, sand and silt deposits stabilized by mangroves and other natural systems will form a natural dyke serving as a safety zone. If infrastructure is developed close to this limit line (3.4m), additional small-scale measures will have to be implemented.

- Strengthening of education programs incorporating training on the value of natural deltas and coastal processes.
- Development of an early warning system and “safe-zones” to protect the local population in case of natural events such as tsunamis, earthquakes and storm-surges.
- Action Plan to cope with the “El Niño” event.
- Development of a research program to study natural coastal processes and the development of adaptation/protection strategies.
- Development of a land use planning system that incorporates risk zones.

Box 7. Protection Measures for Cartagena and Tumaco

Coastal defense and stabilization structures can be used to protect coastlines from SLR effects such as erosion processes, large waves, and flooding. Engineering work is divided into hard and soft structures usually implemented in combination with each other. Hard structures are usually composed of levees and beach stabilization structures. Soft structures are generally natural systems and elements characteristic of the coastal border that can act as effective protection barriers. These comprise beach nourishment and vegetation coverage.

Protection measures to protect Cartagena’s coastline:

- The construction of a longitudinal levee between the sectors of Castillo Grande and El Laguito estimated to cost around 45,000 million pesos depending on what material is used.
- The construction of a 1m high dike on the boulevard of Bocagrande and Castillogrande to protect the beaches of Cartagena Bay.
- The refill of beaches in three tourist sectors of the city – Castillogrande, Bocagrande and La Boquilla – with material extracted near the areas. To guarantee the stability of the fillers, the placed material needs to be confined within two curved lateral groins.
The filling is estimated to cost 4,300 million pesos.
- The construction of protection structures such as walls in the northern part of the industrial area of Mamonal and la Manga.
- The elevation of the ports so that activities conducted in these areas are not interrupted.
- The restoration of marshes on the coastal border of Cartagena and mangroves on Tierra Bomba Island. In both areas potentially affected human settlements will be relocated allowing for natural systems to recover.

Two protection measures have been proposed for Tumaco:

- The relocation of people living in the densely populated area of Tumaco Island and the recovery of the natural vegetation in this area. The people on the coastal border of the Island of Tumaco are living in poverty conditions and are highly vulnerable to tsunamis, flooding and other climatic events. After their relocation takes place, vegetation will be planted in this area allowing mangroves to recover and to create a protective barrier. This area is equivalent to almost 30% of the island.
- The second measure is proposed as an alternative in case people cannot be relocated. This alternative improves the existing road infrastructure on the Island of Tumaco and enhances the activities in the port area and tourism development on el Morro Island. This measure consists of a longitudinal dike that surrounds the Tumaco Island, the elevation of roads, the relief of bridges, the relief of the port area, and the refill of the beach el Morro Island.

In general terms, six adaptation measures are identified for Cartagena and Tumaco (see figure 9).

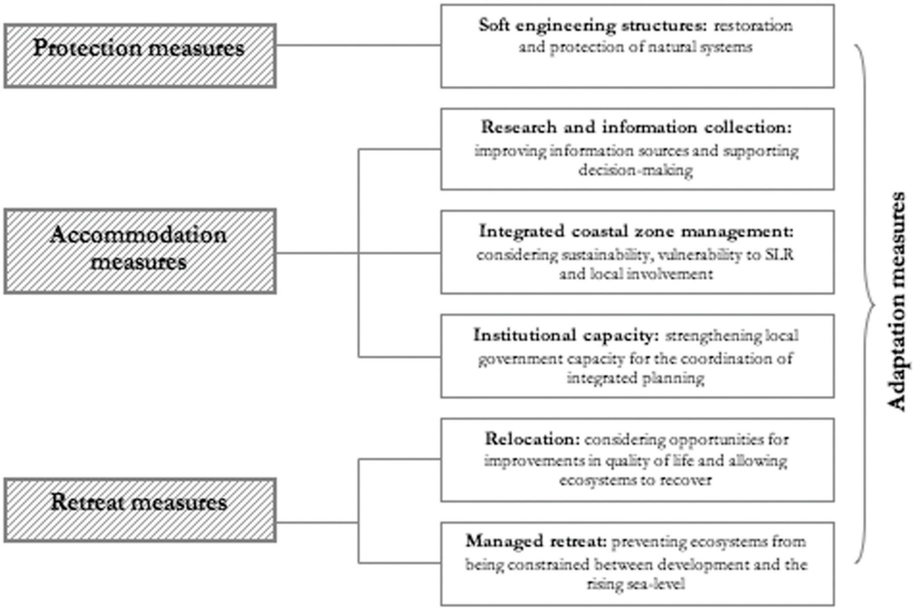


Figure 9. Identified Adaptation Measures to Sea-level Rise for Cartagena and Tumaco

A common theme among all the selected measures is the state of the natural systems. Therefore, it was decided to adopt a strategy that considers the recovering and protection of the coastline's natural systems as an approach that will transverse all measures suggested, regardless of if they are protection, accommodation or retreat measures. To prioritize the identified measures and select the most suitable ones a policy option analysis was conducted for each proposed measure considering the national context. The following section presents a synthesis of the analysis conducted for the three main adaptation strategies selected for Cartagena and Tumaco.

6. Policy Options Analysis

The policy option analysis is carried out within the national context and considers the sustainability guidelines set out under the framework of the Environmental National Policy for the Sustainable Development of Oceanic Spaces and the Coastal and Insular Areas of Colombia (PNAOCI). The analysis is carried out considering the following criteria for each alternative: effectiveness, efficiency, equity, political feasibility and implementation capacity. As a result of the analysis, three strategies are proposed to prevent the impacts caused by the effects of SLR, and contribute to the objectives of the National Disasters Prevention and Attention Plan, the PNAOCI and its Action Plans. This section presents a synthesis of the analysis carried out for each proposed strategy: 1) Integrated SLR-related Risk Management; 2) Coastal Tourism Development; and 3) Research Initiatives and Scientific Development Programs.

6.1 Integrated SLR related Risk Management

The integrated SLR related risk management includes adaptation measures to prevent potential SLR impacts on the coastal area and risk management actions to be incorporated into the territorial organization plans of the departments and municipalities.

6.1.1 Justification

The weak planning and low institutional capacity have affected the incorporation of an integrated SLR related risks management strategy into the development plans at the national and local level. So far, attention has been given to the biophysical, social, and economic aspects of the system's vulnerability to SLR, neglecting the political and institutional vulnerability. These aspects however play fundamental roles and can have large impacts on the overall vulnerability of an area. For instance, institutional weaknesses such as poor coordination among governmental entities and lack of capacity to control coastal productive activities have contributed towards the increase of pressure exerted on coastal ecosystems and the degradation of the environment. This in turn, has increased the overall vulnerability of the area to SLR effects. Moreover, political and institutional vulnerability have negative impacts on the efficiency and effectiveness of policies and measures, the successful adoption of an integrated approach in policies and management plans, the legitimacy of the governmental action, and the participation of the different sectors in policy decision-making and implementation. As a result, weak political and institutional capacity is affecting the incorporation of preventive measures to SLR related risks into development and management plans; delaying necessary action to be taken to increase adaptation capacity to potential impacts in coastal areas.

It is a common view that addressing risks and disasters is the exclusive responsibility of governmental entities in charge of national emergencies, leaving risk prevention and management outside the scope of development planning. The vulnerability assessment conducted in this study reveals that poor socio-economic conditions and the unsustainable use of natural systems contribute to a high vulnerability to climatic hazards such as SLR. In this sense, promoting sustainable development can contribute to decreasing vulnerability and building adaptive capacity. Moreover, land use development has to consider high risk areas and potential impacts caused by SLR to avoid potential losses. To follow up on these issues an integrated SLR related risk management approach has to be incorporated in an organic and systematic way into national and local development strategies.

Although national policies promote the incorporation of risk prevention measures into the territorial development and management plans; this is not always properly done particularly at the local level. The Territorial Organization Plans (POTs) and the Territorial Development Plans (PDTs), as guiding instruments for the long term sustainable development and the short and medium term territorial management, play a strategic role for risk reduction and prevention at the regional and local level. The Local Management Risk Plan constitutes a component of the PDT that focuses on emergencies (Emergency and Contingencies Plan). This plan is supposed to include actions and investments defined in the POT to avoid disasters, reduce existing risks and prevent new risks. Therefore, the POT and the Local Risk Management Plan constitute the best mechanisms to incorporate an integrated SLR related risk management strategy into local sustainable development planning.

In the particular case of Cartagena and Tumaco, an integrated SLR related risk management approach has not been incorporated into their POTs yet[13]. This option analyzes the actions and considerations necessary to follow up on this process and successfully implement an integrated SLR-related risk management in the study areas.

6.1.2 Option Analysis

To ensure that the integrated SLR-related risk management is effective, it must be in line with the Territorial Organization Plan objectives and the Development Plan strategies. It should be framed as a sub-program of these plans and include different projects that aim at optimizing the use of land and natural resources according to the potentials and the vulnerability of the area.

13 Tumaco is currently developing its Territorial Organization Plan.

Moreover, to ensure the effectiveness of the integrated SLR-related risk management it is important to incorporate the identified protection adaptation measures to SLR into the different planning instruments. By doing so, a more preventive approach will be adopted in the decision-making related to risks and investment in coastal areas. The adaptation measures should be in line with climate change policy and the integrated management strategies proposed under the coastal water loggings regulation, the regulation on the uses and activities in areas threatened by flood, and the regulation on the protection of areas considered of vital socio-economic interest.

So far, a certain level of coordination has been reached at the national level for the incorporation of an integrated risk management approach into development policies. However, at the local level the situation is different. POTs have not successfully incorporated an integrated risk management strategy. The success of this process at the local level will highly depend on: 1) available information and scientific research to support decision-making; 2) a degree of compromise between civil society and the private sector; 3) the financial support and investment for risk management; 4) a better coordination between local authorities, planners and decision-makers; and 5) the adoption of a long-term perspective in the decision-making process.

Although there are no known references to estimate costs and benefits to assess efficiency, it is possible to say that the integrated SLR related risk management has several benefits. Among the main benefits are: supporting the project investment decision-making process by incorporating the risk factor related to SLR; providing relevant information and reducing scientific uncertainty and information gaps that hinder adequate decision-making in coastal management; and supporting the integrated management of coastal areas. Costs may include necessary investments in: conducting research to improve the methodologies used to develop scenarios; generating databases with indicators; establishing networks to facilitate efficient access to information; training communities and investors in risk management; and building protection measures against SLR.

In terms of equity, the people that benefit from implementing an integrated SLR related risk management are: the national government by improving the planning and decision-making process; the territorial bodies and their environmental authorities by gaining the capacity to prevent risks; and the communities in general by becoming less vulnerable and improving their quality of life. On the other hand, the entities that will assume the costs of this implementation are: the national and local governmental bodies, the international community that support the initiative and the private companies that perform research for project development.

With regards to political feasibility, the potential allies of this strategy are the Inter-American Development Bank that helps countries to integrate risk reduction into their planning and development investments; the United Nations Development Program; the Ministry of Environment; Housing and Territorial Development; different governmental entities; communities; research institutes; and investors. Opponents to the strategy are entities that see their interests affected by its implementation such as large landowners; industry; illegal occupants; and pressure groups (armed sectors). To manage the opposition, some actions have been considered: 1) ensure the participation of different stakeholders in the planning processes; 2) create awareness among investors and civil society in general, particularly among the communities settled in the most vulnerable coastal areas; 3) develop an integrated information system; 4) consolidate follow-up and monitoring networks; and 5) establish mechanisms to overcome current challenges, such as financial constraints. In general terms, the possibility of implementing this strategy is high, because there is already a political framework and normative framework that would facilitate the adoption of an integrated SLR-related risk management

The political feasibility is directly related to management capacity, in that the existence of a policy and normative framework regarding risk prevention and attention matters, coastal and insular development, water loggings management and territorial organization and planning set the necessary basis to implement an integrated SLR related risk management strategy. In addition to these already established policies and regulations, Colombia has the vision to pursue an integrated management of its coastal areas (MIZC), setting a favorable condition for the adoption of this strategy. Moreover, the incorporation of an integrated SLR related risk management strategy could be assisted by the current institutional framework that has the potential to provide support at the national and local level for its implementation.

Nevertheless, to ensure an appropriate management capacity, some improvements are necessary at the institutional level. Among the most important required changes is the reinforcement of the inter-institutional coordination mechanisms to make the existing system operational and enhance the effectiveness of risk-related policies and regulations. Moreover, it is important to consider that the current institutional and local structure is rigid and any transformation that implies the adoption of political decisions, political will, budget allowances and modifications makes institutional changes slow and difficult.

In summary, the possibility of implementing the proposed strategy is supported by an existing policy, normative and institutional framework, as well as several allies who benefit from its implementation. These conditions could make this strategy politically feasible. However, the identified obstacles, weaknesses and actions necessary to improve the management capacity and ensure the strategy's effectiveness represent difficulties that challenge the success of its implementation. As a result, the probability of this strategy being successful has been estimated to be moderate (less than 75%).

6.2 Coastal Tourism Development

Coastal tourism development refers to a tourism development model that incorporates environmental sustainability of coastal ecosystems and services as an essential asset for the development of the sector. This sector will be integrated into the regional economic, social and environmental dynamics.

6.2.1 Justification

Currently, the tourism industry has the highest growth rate within the global economy. This industry is constantly innovating to face market competitiveness and meet growing demand. Tourism companies are specializing their services and increasing the diversity of products targeting different market segments. As a result, different options are available to the tourists including: cultural tourism, sports tourism, nautical tourism, ecotourism, agro-ecotourism, among others.

Colombia has significant comparative advantage for the development of costal tourism. The country's geographical location gives access to important areas of the Caribbean Sea and Pacific Ocean, as well as to different islands. The coasts are accessible all year round and offer different tourism alternatives such as nautical tourism and ecotourism. Cartagena is the largest tourist destination in Colombia. Tourists primarily visit Cartagena for leisure and recreation. Baru Island has a particularly great potential for coastal ecotourism due to its excellent beaches. Tumaco also has diverse ecosystems and a rich biodiversity that make this area highly attractive for developing ecotourism. However, the tourism industry in Tumaco is still incipient and lacks proper infrastructure. The development of ecotourism in Tumaco would bring significant socio-economic and environmental benefits by diversifying the local economy, inducing the establishment of micro-enterprises, generating local employment, improving transport and communication infrastructures, and reducing the impacts on ecosystems and cultural heritage.

Although environmental quality and ecosystems integrity are a fundamental part of the product and services offered by the coastal tourism industry, the uncontrolled growth of this activity and the unsustainable use of the natural resources are negatively affecting it. In Colombia, the coastal tourism potential is challenged by infrastructure deficiencies and the degradation of beach ecosystems and environmental quality in general. This has a negative impact on the above mentioned comparative advantage of the country not allowing it to compete successfully in the international tourism market.

In addition to the threats mentioned above, the tourism industry could be seriously affected by SLR. Flooding and erosion caused by SLR could damage the tourism infrastructure and affect the beach ecosystems that are one of the main assets in this industry. In doing so, SLR could put public and private investment at risk. So far, there is great uncertainty among investors regarding how climate change effects, such as SLR, could impact the tourism industry. Nevertheless, if environmental quality and natural systems are recognized to be essential resources for tourism, it is necessary to focus on their management and risk prevention strategies to avoid enormous losses for tourism activity and investment.

To enhance the competitiveness of coastal tourism in Colombia, and in this case in Cartagena and Tumaco, it is necessary to develop appropriate planning that considers the different elements that play an important role in this activity. In this sense, the tourism development plan has to integrate adequate management of resources into the destination areas, infrastructure, marketing activities, legislation, land use planning, vulnerability and risks. An integrated approach to developing coastal tourism could determine the difference between developing a competitive tourism market that contributes to the long term sustainable development of coastal areas or an uncompetitive market that will not be sustained over the longer term. A coastal tourism development strategy proposed for Cartagena and Tumaco which adopts this approach and considers several factors for its successful implementation is analyzed below.

6.2.2 Option Analysis

Tourism could effectively contribute towards the sustainable development of Cartagena and Tumaco if carried out with respect to the natural and cultural environment, rationally using natural resources and considering the vulnerability of destination areas. To be effective the conceptualization of the tourism development plan must combine knowledge of nature, the understanding of traditional local cultures and the objectives of sustainable development.

Moreover, to ensure effectiveness a work plan for tourism development must be established to guide its development in such a way that it contributes towards local socio-economic development and the conservation of natural systems, whilst enhancing the protection and adaptation of vulnerable areas to climatic events such as SLR. In doing so, it is fundamental to include in the work plan strategies for the revitalization, restoration, accommodation and protection of natural systems such as beaches, mangroves and water loggings within the areas of tourism interest.

To adopt a more integrated approach to the tourism development plan that considers the elements and strategies mentioned above, it is critical to have access to useful information that will assist in decision-making. For instance, the vulnerability assessment and the adaptation measures identified in this study could contribute towards preventing impacts related to SLR and reduce risks in coastal tourism areas. Providing information to the tourism industry on how climate change effects such as SLR could impact the coastal area provides relevant information needed to develop and integrate suitable adaptation measures into tourism development plans. Also, training the sector's human resources on the subject of risk management would contribute towards adopting a more integrated approach in tourism development plans. Finally, efficient tourism planning has to be a continuous and dynamic process, therefore policies and plans have to be flexible and allow for adjustment to changing circumstances. Currently, the conditions exist for tourism development plans to be designed and coordinated by different interested entities and incorporated into Regional Development Plans, Territorial Organization Plans and Disasters Prevention and Attention Plans. However, the success of this process will depend highly on institutional cooperation, the quality of tourism services, environmental quality, and vulnerability of destination areas, as well as available information on potential tourism in the coastal areas (in the case of Cartagena and Tumaco).

Although there are no known references to estimate costs and benefits and assess the efficiency, it is possible to mention that among the main benefits of this strategy are: 1) the development of an integrated long-term sectoral plan for tourism development; 2) the conservation and promotion of natural and cultural "assets"; 3) the diversification of the regional economy and generation of local employment; 4) the reduction of pressures exerted on the natural systems and the cultural patrimony; 5) the contribution to sustainable development; and 6) research on natural attractions, cultural traditions and values. Among the costs are investments in: the design and establishment of a monitoring system for tourism activities in coastal areas; the establishment of networks to facilitate information; the development of measures to reduce vulnerability; the development of research; and capacity building.

In assessing equity, the beneficiaries of implementing a tourism development plan are: communities with an opportunity to diversify their economic activities; the country and the municipalities that will generate more income; the international community that has the opportunity to visit and value the natural and cultural heritage; the tourism sector that can improve the decision-making for investment and development; and the territorial entities and their environmental authorities that will improve their decision-making capacity. On the other hand, the entities that will assume the costs of implementing this strategy are the national government; the Ministry of Commerce; Industry and Tourism; the Development Projects Financial Fund (FONADE, an industrial and commercial enterprise of the government); local governments; private companies performing research to develop the tourism sector; and the international community that supports ecotourism development initiatives and projects.

In terms of political feasibility, the potential allies of this strategy are: the Inter-American Development Bank by financing studies and investment projects that contribute towards tourism development in the member countries; the United Nations Development Program; the Ministry of Environment; Housing and Territorial Development; the National Planning Department; the environmental authorities of Cartagena and Tumaco; the communities; investors; and research institutes. The potential opponents are interest groups affected by the implementation of this strategy including: industry; the armed groups; the large landowners; and the illegal occupants. To manage the opposition it is necessary to: 1) guarantee the participation of different stakeholders in the different planning processes; 2) create awareness about tourism activities and conservation practices for ecotourism development among investors, society in general, and local communities in particular; 3) design and implement an information system for the Colombian Caribbean and Pacific littoral; 4) consolidate the tracking and monitoring networks; and 5) set out mechanisms to overcome the limitations, especially financial limitations, and to facilitate the implementation of an integrated tourism development plan.

The feasibility of this strategy is supported by the management capacity that currently exists in the country. The already established policy framework in Colombia regarding coastal and insular development, water loggings management, climate change, and risk prevention and emergencies facilitates the integrated tourism development in coastal areas. Moreover, Colombia has specific policies and plans for tourism development at the national, regional and local level. In the case of Cartagena, these are: 1) the Colombian Caribbean Littoral Master Plan that identifies Cartagena's tourist products for potential businesses; 2) The Cartagena de Indias Sectoral Tourism Plan (04 to 07) incorporated into the General District Development Plan; 3) the Tourism Policy guidelines; and 4) the POT. Tumaco has 1) strategies to support the Development of the Nariño Department that foresees an enormous potential for the agro-ecotourism in the area and identifies natural, cultural and theological attractions; and 2) the Tourism Sectoral Plan (03 to 06) framework that identifies the region as a cluster with potential for tourism. In addition to the policy framework, existent laws and decrees in the country form an adequate normative framework for the development of tourism in coastal areas.

Although established policies and regulations contribute to the management capacity necessary for the implementation of this strategy, this process could be jeopardized if the institutional capacity, which in this case involves different entities at the national and local level, is not strengthened by: 1) reinforcing the inter-institutional coordination mechanisms at the local and national level; 2) strengthening the decision-making capacity in institutions; 3) setting up mechanisms to obtain financial resources; 4) implementing monitoring and evaluation mechanisms for tourism-related policies and activities; 5) increasing the institutional capacity to ensure compliance; and 6) increasing flexibility in the institutional structure to allow for modifications along the way.

To conclude, the possibility of implementing the proposed strategy is supported by an existing policy and normative framework and several beneficiaries of this strategy. The combination of these conditions contributes towards the political feasibility of this strategy. However, if the identified difficulties and necessary actions to successfully implement the strategy are considered, the success probability of this strategy is estimated to be moderate (less than 75%).

6.3 Research Initiatives and Scientific Development Programs

Research and scientific development programs refers to the establishment of an inter-institutional and interdisciplinary research collaboration group in the country to facilitate and generate research and information of high quality on the subject of climate change and its associated effects on the Colombian coastal areas.

6.3.1 Justification

Scientific and technological research fulfill an important function by providing the necessary information and understanding to solve problems, maintain or change systems, make use of resources and plan for future developments. The achievement of the Colombian 2019 Vision will require an important input of scientific and technological information, not to mention the high level of institutional cooperation and investment this will demand. Considering the current deficiencies in national research capacity and available information, this could indeed become an obstacle for the achievement of the 2019 Vision.

Among the main difficulties that currently affect research development in Colombia are the problems related to gathering information aggravated by the deficient inter-institutional cooperation between research entities. Moreover, different methodologies and time periods used for research cause discrepancies and complicate data interpretation and analysis. In addition, information is deficient due to data gaps and scientific uncertainty. This is mainly because research entities in Colombia are going through serious difficulties to finance their operations and projects, resulting in research underdevelopment and insufficient information to properly contribute to the national and local decision-making, planning and evaluation processes.

With climate change, there is a general lack of knowledge and information about its effects and possible impacts on the country. Moreover, there is only weak cooperation between the research community and the entities in charge of the policy decision-making process regarding the reduction of climate change related risks. To date, the best national-level results obtained on the potential impacts from climate change effects, as well as on adaptation capacity, are found in the First National Communication of Colombia to the United Nations Convention Framework on Climate Changes coordinated in 2001. Although Columbia has some information on this subject, this mainly corresponds to individual institutional efforts with differing objectives without any long-term planning focused on establishing a coordinated research and policy path.

These deficiencies and difficulties to developing research in the country hinder proper planning based on high-quality information and coordinated work to achieve common goals. To improve this situation, it is necessary to strengthen national scientific and technological research, and institutional capacities. Among the important steps to be taken is the establishment of a research policy course that is relevant and coherent to the needs of the country. The strengthening of the inter-institutional cooperation to develop and carry out joint-research programs is also fundamental. For instance, the complexity of conducting research on vulnerability to climate change effects calls for combining efforts and coordinating inter-institutional work complementing expertise, disciplines and resources. While this could facilitate obtaining financing resources, it could also improve the research quality. This information could then be used as relevant input to support the development of policies and strategies. This important step could be complemented by the improvement of access to quality information and the enhancement of public participation in the decision-making.

The proposed strategy focuses on the improvement and strengthening of research capacity in the field of marine and coastal sciences and climate change. A new approach is proposed and a set of considerations are outlined for the implementation of a research program that promotes inter-institutional cooperation and multidisciplinary research. This approach is based on the adoption of a long-term vision for research development in marine and coastal sciences so that it incorporates the challenges and effects that climate change generates over time. The strategy includes the development of competitive scientific and technological research capacities; the sustainable financing of research programs and projects; the construction of a national culture centered on science and technology; and the engagement of the business sector with regional science and development.

Finally, it is important to mention that the proposed option is in line with the National Pact for Technological Innovation, where the academics, the researchers and technological development players agree to focus their efforts on strengthening national work and their association with international research networks creating Investigation Centers of Excellence. The strategy also contributes to the new Law Project for Science and Technology that will soon be presented to the Congress of the Republic, the objectives of the Science and Technology Plan 2020, the science and technology component of the 2019 Vision, and the Investigation Agenda for the Free Trade Treaty.

6.3.2 Option Analysis

To ensure the effectiveness of this strategy and improve the research capacity in the country in coastal and marine sciences and climate change, it is important to enhance inter-institutional cooperation by supporting the development of joint-research in strategic areas of the Colombian coastline. In this way, research will not be conducted individually and the efforts to produce scientific information of national importance will be combined. It is also important to enhance scientific cooperation at the international level by promoting an open exchange of quality information in marine and coastal sciences and global climate change.

Moreover, for this strategy to be effective it is essential to create the mechanisms to increase the participation of science and technology researchers in the decision-making process, in particular in the planning of adaptation and mitigation to climatic events in coastal areas. If this strategy is effective and research capacity is enhanced in the country, the generated information could become a strategic input for the development of a knowledge-based economy. In such a scenario, Colombia could plan its development and increase its productivity and competitiveness within the international context based on the generation, diffusion and use of knowledge. This focus requires the construction of a long-term vision with clear plans to align research and policy development paths with consideration for the challenges created by climate change.

Currently, there is an interest in the country for the coordination of inter-institutional and multi-disciplinary research, as well as for information generation for the decision-making and planning processes. For example, Colombia has developed a structure that seeks to optimize the interaction between different governmental entities called the national sciences and technology system (SNCyT)[14]. This already established inter-institutional network could set the conditions for the

14 The SNCyT consists of the Ministries of Education, Foreign Commerce, Economic Development, Agriculture, Health, Mines and Energy, Communications and Environment, among others.

implementation of this strategy. However, the success of this process will depend highly on overcoming challenges related to: the lack of coordination between the different entities that form the current national science and technology system; the limited budget allocation for scientific and technological research; the low number of researchers in the field of coastal and marine sciences; and difficult access to quality information.

Although no references could be found to estimate *efficiency* based on costs and benefits, it is possible to mention that among the main benefits of this strategy are: 1) the improvement of the scientific and technical research capacity and the structure of the involved institutions; 2) the improvement of public knowledge and the quality of information for decision-making particularly regarding global climate change and the effects on coastal areas; 3) the development of quality information to respond in a more scientific and strategic way to the engagements agreed under the Climate Change Convention and the Kyoto Protocol framework; 4) the consolidation of a new scientific research system for the marine and coastal areas; 5) the improvement of cooperation among different research entities at the national and international level; and 6) easier access to quality and relevant information. Among the costs are investments needed to cover the design of methodology and data standards that can be incorporated into different research processes, the design of indicators and methodologies, the improvement of research facilities and infrastructure, capacity building of human resources, and the development of an information system on climate change.

In terms of *equity*, the beneficiaries are: 1) the national government and local authorities by improving the planning and decision making process, particularly regarding climate change effects and integrated management of coastal areas in the country; 2) the SNCyT by strengthening its capacity; and 3) the general public, investors, companies and local communities, by having greater access to quality information. On the other hand, the entities that assume the costs are the Inter-American Development Bank that supports capacity building for risk reduction management; the World Bank; the organizations and/or countries that signed scientific research cooperation agreements with Colombia; and finally, the national government, the Ministry of Environment, Housing and Territorial Development and the National Royalties Fund.

In terms of the *political feasibility*, the allies are considered to be the Inter-American Development Bank that contributes towards the countries' capacity to integrate risk reduction into their planning; the working group proposing the Science and Technology Law Project to the Congress of the Republic; and the governmental entities related to planning, environment and research. This strategy has no opponents since no entities find their interests affected by its implementation.

The political feasibility of this strategy goes hand in hand with the *capacity management* that the country has built to date. Colombia has a vision that aims at improving its research capacity so that the country's science and technology become competitive at the international level improving access to strategic knowledge and information. This vision sets favorable conditions for the development of the proposed strategy. The strategy is supported by an existing policy framework in the country that promotes: the exchange and cooperation between national and international research centers; the generation of information as the basis for integrated management planning; the establishment of guidelines for science and technology policy (coordinated by Colciencias[15] during the 2002 to 2006 period); the development of the national science and technology policy (included in the National Council of Economic and Social Policy – CONPES document 3080 coordinated in 2000) and the development of national environmental research (Environmental Research National Policy).

15 Colombian Institute for Technological and Scientific Development

The *capacity management* to implement this strategy is not only supported by a policy framework, but also by a normative and institutional framework. Among the entities that could directly be involved with the implementation of this strategy are Colciencias, the SNCyT, research institutes, universities, NGOs and the private sector. However, to create the right conditions and capacity management for the implementation of this strategy, it is necessary to strengthen the cooperation between the different entities involved and to reinforce their research capacity. To do so, financial resources and training will be essential.

In summary, the *possibility of implementing* the proposed strategy is supported by an existing policy, normative and institutional framework. This framework combined with several interest groups that benefited from this strategy contributed towards the political feasibility of this strategy. Taking into account the current weaknesses and obstacles, and all the necessary considerations to ensure this strategy's efficiency and effectiveness and the actions needed to improve the management capacity for its successful implementation, the *success probability* for this strategy is estimated to be high (above 80%).

7. Lessons and Strategic Recommendations

7.1 Lessons Learned

Long-term planning is essential

To adapt effectively to SLR and other climate change effects planning needs to start at least 10 to 30 years ahead of time. At times it will be necessary to plan for the relocation of people, habitats and buildings. To do so cost-effectively early action is required. Moreover, to cope with the uncertainty related to climate change and coastal dynamics, flexibility in management and planning is necessary.

Think and act in a wider context

The boundaries used for territorial planning do not consider the boundaries of Environmental Coastal Units.[16] To adopt a flexible and responsive approach to deal with coastal change, planning and action needs to consider a much wider spatial context which includes managing freshwater catchments and coastal units.

Work in favor of nature not against it

Experience has demonstrated that working while respecting natural processes is the most sustainable approach. In some cases, this will mean undoing past mistakes by destroying physical structures and allowing the coast to recover naturally. In other cases, it will be necessary to divide action into phases, implementing temporary solutions in the short-term whilst allowing natural defenses to develop in the medium and long-term.

Solutions need alliances

Given the impact that decisions taken today may have on the site and the surroundings, it is not possible to operate in isolation. Facing the problems and challenges affecting the study areas requires collaborative action between the local population and neighboring coastal owners and managers. Mutually beneficial solutions like large-scale realignment projects can only be achieved by adopting a strong partnership approach.

16 Colombia has 3 coastal planning regions: Caribbean Insular, Caribbean Continental and Pacific. Each of these regions has different socio-economic characteristics. Moreover, each of these regions is divided into Coastal Environmental Units (CEUs). There is a total of 12 CEUs in the coastal area of Colombia. Each CEU is different and has particular biotic and physical characteristics that define its specific management. For each unit an administrative structure has been proposed to empower institutions and local communities to implement measures that would reduce natural and human induced hazards.

Involvement is critical
Raising awareness of the potential impacts of climate change effects in coastal areas is vital to gain public trust. Any strategy that implies realignment of the coast could create uncertainty and even hostility among the local population. Therefore, building consensus and providing information is fundamental and crucial to find sustainable solutions. This process takes time and effort, but INVEMAR is not alone in building capacity. All coastal institutions face the challenges generated by climate change and SLR. To cope with these challenges and plan the development of the coastal areas, these institutions need a common approach that manages the risks these changes may bring.

7.2 Recommendations

- The study has determined that SLR will have mainly negative impacts since it will cause sea intrusion, erosion and flooding, among other effects that will affect both study areas. Therefore, a deeper study of the consequences of SLR is crucial, to define how impacts can be reduced.

- However, it is important to note that SLR can also result in some positive effects. It is therefore important to carry out more research into the potentially positive impacts so that adaptation measures can be developed to diminish the negative effects but seize the positive benefits generating new opportunities for sustainable development.

- Risks related to SLR and other climate change effects have not been included in any management plan or development policy at the national, regional or local level. The country must implement adaptation measures as soon as possible so that these act as preventive measures (planned adaptation) and not as reactive measures, which are more expensive and more difficult to implement. The planning process should be continuous, participative and flexible allowing for changes along the way.

- To implement the most suitable adaptation measures and strategies it is important to first build capacity. In this sense, this study has been critical as it generates relevant information and discussion among stakeholders to support the decision-making process into the reduction of SLR related risks. This study has also identified considerations and actions that have to be taken into account to achieve successful implementation of the proposed adaptation strategies.

- Indicators have to now be designed at the local level to define the effectiveness of adaptation measures over time; local institutional capacity has to be strengthened; more research and quality information has to be produced to support decision-making and planning; and involvement and cooperation between stakeholders has to be enhanced.

- Given the constant threat of tsunamis in Tumaco and large daily tide variation, it could be considered that this area has a high response capacity to sea level changes. However, the state of their natural systems which have been greatly affected by human activity has converted Tumaco into a highly vulnerable area. In the future, this situation will worsen. Therefore, more studies and actions have to be developed in Tumaco (as well as in Cartagena) that focus on increasing adaptive capacity by decreasing the susceptibility of natural systems.

- During the last workshop in Cartagena, stakeholders suggested that the study area for Cartagena should be expanded to the south, where better preserved mangroves are currently facing pressures from industrial and urban expansion. Coral reefs are also presented in this area that together with the mangroves could serve as potential natural barriers to reduce wave impact.

- The ability of humans and natural systems to adjust and adapt to SLR lies in the interdependence between socio-economic systems and natural systems. This interdependence is evident in the study areas where the sustainability of livelihoods depends on the quality of ecosystems and the environment, as well as on access to and the use of natural resources. Therefore, given future uncertainties and the development objectives in both areas, enhancing natural systems' resilience in Cartagena and Tumaco should be prioritized as an adaptive strategy.

- In the process of implementing adaptation strategies, it is important to consider the culture in both study areas. Previous efforts to introduce risk prevention measures into these areas have failed due to a lack of understanding about the culture. Therefore, it is necessary to engage different stakeholders in the process, in particular it is crucial to inform the local communities about the risks and involve them in the process. Likewise, the involvement of the private sector is indispensable.

- Another important challenge for the successful implementation of adaptation strategies is financial support. This issue has created conflict in the past because it is not clear who should be the responsible entity to cover the expenses to introduce these measures.

- Finally, to improve the quality and availability of information it is necessary to develop a network of information exchange and strengthen the inter-institutional cooperation between research and governmental entities.

ANNEXES

Annex 1. Natural Susceptibility Index

The Natural Susceptibility Index has the following components:

BSI = ßEQ + €EC(THL) + θWQHPI + θRA + θLU(HC) + θTH

where,

BSI = Natural Susceptibility Index

and,

EQ= Ecosystem Quality Indicator
EC (THL)= Ecosystem Cover Indicator
WQHPI= Water Quality and Hydrographic Processes Integrity Indicator
RA= Recovery Areas Indicator
LU(HC) = Land Use Indicator
TH= Hazards Indicator

and the weights given to the indicators are ß, €, θ

Values	Susceptibility Level
> 81	High
61 – 80.99	Medium-high
41 – 60.99	Medium
21 – 40.99	Medium-low
0 – 20.99	Low

The highest value for the Natural Susceptibility Index is 100. An increase in value denotes an increase in the susceptibility level. To simplify the analysis of the BSI the following classification is used.

Annex 2. Socio-economic Vulnerability Index

The Socio-economic Vulnerability Index has four components:

SVI = LQI + NCRI + PII + P

where,

LQI = Life Quality Indicator
NCRI = Natural Catastrophe Risk Indicator
PII = Public Investment Indicator
PI = Population Indicator

The Life Quality Index is based on the methodology[17] used to calculate Colombia's Life Quality Index.

$$ICV_i = \sum_{f=1}^{F} \sum_{j=1}^{C_f} W_f W_{fj} V_{fj}^i$$

where,

W_f is factor associated weight, factors are sets of variables incorporated to the indicator.
W_{fj} is variable j weight, belonging to factor *f*
V^i_{fj} is the valuation received by *i* commune in the response category that belongs to *j* variable of *f* factor
F is the number of factors
C_f variable number in each factor
i is the commune

The Natural Catastrophe Risk Indicator is the potential risk of partial or total household destruction as a result of natural events given an inadequate household location.

$$IRCN_i = \sum Y_j Z_j^i$$

where,

Y_j is variable *j* weight, belonging to the factor
Z^i_j commune *i* value in *j* variable

The Public Investment Indicator represents the expenses designated to health, education, infrastructure, aqueduct and sewer construction, household and disaster prevention. Besides assessing vulnerability, this indicator allows evaluation of adaptive capacity in case of natural disasters such as flooding as a result of sea-level rise.

$$IIP = \sum X_j K_i^j$$

where,
X_j is variable *j* weight, belonging to the factor
K^j_i commune *i* weight in *j* variable

Finally, the Population Indicator indicates the participation of population in a given geographic area (Government Commune Unit for Cartagena) from the municipality's total population.

17 For more details on this methodology see Gamboa, González, Cortes, 2000

where,

$$IP = \sum J_j R_i^j$$

J_j is variable j weight, belonging to the factor
R_i^j is the value received by i commune in j variable

Finally, the Socioeconomic Vulnerability Index values are located in the range [0,100]. An increase in the value indicates that the vulnerability diminishes. To simplify the analysis of the SVI the following classification is used:

Values	Vulnerability Level
Under 15	Very high
15 - 28.9	High
29 - 42.9	Medium-high
43 - 56.9	Medium
57 - 69.9	Medium-low
Above 70	Low

Annex 3. Indicators for Natural Susceptibility Assessment

Ecosystem coverage	Estimates the total area covered by an ecosystem in a given area. It focuses on the changes of natural vegetation cover that can impact biodiversity and an ecosystem's integrity. This contributes towards defining how ecosystems behave under different pressures and if protection measures are necessary to preserve them.
Water quality and hydrographic processes integrity	Is used for aquatic and associated terrestrial ecosystems. Water quality is measured based on a set of physical, chemical and biological parameters. If the parameters do not fall within the standards, water quality might be affected. Possible causes can be identified based on the measurements.
Ecosystem quality	Provides an idea of the state of the ecosystems found in the area and the different pressures affecting them, giving an idea of their resilience capacity.
Recovery areas	Areas where measures and policies have been adopted to improve ecosystems' quality and reduce the pressures on them. It also includes areas where natural recovery processes are taking place.
Land use: habitat conversion	Identifies changes in land use and pressures put on different ecosystems. It is obtained from analyzing land use maps and available historical data.

Hazards	Climate hazards are referred to as climate change effects such as droughts, floods, storms and heavy rainfall, among others. The identification of the hazards in a system contributes to understanding the factors that make a system more or less vulnerable, foreseeing possible strategies to increase the system's capacity to adapt.

Annex 4. Indicators for Socio-economic Vulnerability Assessment

Life quality	Composed of variables that evaluate water supply, sewage disposal, garbage disposal and cooking fuel.
Services	Groups variables concerning cooking fuel, water supply source and sanitary service.
Housing	Includes external wall materials and type of floor used for housing construction.
Human capital factor	Measures a population's education. It is composed of the proportion of the population that receives education and is analyzed by age ranges.
Natural disasters	Measures the population's perception with respect to the vulnerability of their house location to natural disasters such as flood, avalanche, landslides and others.
Public investment indicator	Includes investment in health, basic education, infrastructure, housing and disaster prevention. Disaster prevention is the variable with the highest weight in this indicator so that municipalities' vulnerability to SLR can be evaluated.
Population indicators	This indicator is composed of the number of inhabitants and the number of houses inside the Government Commune Units.

Ghana Country Report

William Kojo Agyemang-Bonsu, Bill Dougherty, Amanda Fencl, Eric Kemp-Benedict

1. Introduction

The project carried out in Ghana under the Netherlands' Climate Assistance Program (NCAP) aimed at exploring the linkages between poverty alleviation, climate change, and adaptation responses. There were numerous activities and outputs of the project spread over two distinct phases during the period 2003 to 2008, and all were underlain by the overriding goal of developing a national approach to mainstreaming climate change concerns into ongoing development efforts that address poverty, adverse impacts from climate change, and new planning frameworks in a conterminous way.

The Ghanaian economy depends heavily on the agriculture, forestry, and fishery sectors, all of which are highly sensitive to projected climatic fluctuations. As many have noted and which is widely recognized in Ghana, the adverse impacts associated with climate change will most likely hit poor rural communities the hardest; the very communities engaged in agricultural production, dependent on annual yields of forests, and fishing for their livelihoods.

Rural communities in Ghana can be characterized by a relatively high incidence and extent of poverty, higher fertility rates, higher biomass usage, fewer infrastructure facilities, lower educational status, and lower health status. The overwhelming majority earn no more than about $2 per day, rendering them the least capable of adapting or coping with increasing climatic hazards.

The urban poor are another group vulnerable to climate change in Ghana. Typically living in unplanned settlements (slums and densely populated areas) located along the coastal areas, or close to surface watercourses and stagnant drainage systems, it is likely that they will face increased flooding, rising sea levels, and new public health risks as temperatures rise and disease vector distribution patterns shift.

These inescapable perceptions form the basis of the NCAP effort in Ghana. Also, since climate variability and climate change had not been seriously addressed in national policymaking dialogues at the time the study was launched, there has been growing concern that climate change could undermine national poverty reduction strategies and render development targets unmet. Subsequently, mainstreaming climate change into the Ghana Poverty Reduction Strategy (GPRS) was a critical starting point for the Ghana NCAP project.

At the broadest level, the effort to mainstream climate change into development activities was carried out in two distinct phases. The first phase focused on the development of climate change, the conceptualization of socio-economic development scenarios and the preparation of sectoral vulnerability and adaptation assessments. Taken together, activities in the first phase were essential in developing a better understanding of socioeconomic vulnerability to future changes in temperature and precipitation regimes. They were also instrumental in the identification of the range of potential adaptation strategies that would build resilience in local communities against climate risks in the agriculture, fishery, land management, and public health sectors.

The second phase of the effort attempted to build on these results and develop a strategy to integrate the outputs of sectoral vulnerability and adaptation assessments into national development planning. A key feature of this process was extensive consultations with a wide range of stakeholders through public workshops and forums, with the aim of capturing salient input on the project's emerging understanding of vulnerability and potential adaptation strategies. The workshops also helped to develop national capacity in methodological approaches and analytical tools for the prioritization of adaptation options. Overall, the key output for the second phase was the national adaptation policy framework and its direct application in the preparation of an adaptation project portfolio for Ghana.

The rest of this report describes the process, activities, results, and lessons learned associated with the Ghana NCAP projects. The next section describes the rationale and key objectives of the project. In Section 3, key results and finding are presented. Finally, section 4 presents lessons learned. A numbers of annexes are also included that provide additional detail for some of the key activities and processes.

2. Rationale and Objectives

As background, it is important to note that Ghana participated in the earlier climate change assistance programme offered by the Dutch government. The Netherlands Climate Change Studies Assistance Programme (NCCSAP) ran from 1996 to 2003 in Ghana and provided technical support for the preparation of climate changes projections, as well as vulnerability and adaptation assessments for water resources, coastal zones and agriculture (cereal production). As such, the current NCAP project was able to benefit from and build upon the significant level of capacity enabled by the earlier NCCSAP.

The technical outputs of the NCCSAP project were instrumental in shaping a broad understanding in Ghana regarding the likely evolution of the climate system in the West Africa region. The outputs of global circulation models indicate that a temperature rise of about 1˚C, a 20% reduction in rainfall, and a 30% reduction in runoff would likely occur around the middle of this century. As the regional climate changes, many of Ghana's physical and biological systems were determined to be at risk. Indeed, Ghana's natural systems were found to be vulnerable to more frequent droughts and floods, particularly impacting ecosystem-based livelihoods like fishing and farming. Moreover, growing aridity would reduce groundwater recharge and an increasingly arid climate would lead to the depletion of biodiversity and desertification.

While the Ghana NCAP project continued NCCSAP's focus on vulnerability and adaptation studies, its motivating rationale was the need to better understand the linkages between poverty and climate change and the way in which the livelihood systems of poor communities could be affected. Given the results of the previous climatic modelling and vulnerability assessments, the driving question was how could adaptation responses be introduced that would mitigate the harm to rural communities already confronted with persistent poverty. The formulation of climate change policies that could complement and strengthen existing national policy documents addressing poverty alleviation – most notably the Ghana Poverty Reduction Strategy (GPRS) prepared in 2005 by the National Development Planning Commission – was a key strategic objective.

This was considered a crucial point of departure for the NCAP project because of the readily apparent weaknesses of the GPRS. Although Ghana's poverty reduction efforts and the GPRS itself do indeed recognize a number of environmental issues that affect quality of life, climate variability and change have not been included. When compared to other national policy documents addressing development issues, this is not particularly surprising – the impacts associated with climate variability and climate change on poverty tend to be overlooked at worst or only implicitly acknowledged at best in key national policy documents. The Ghana NCAP project's outputs, as summarized in the next section, addressed this important gap in a proactive way.

3. Key Results and Findings for Phase 1

At the operational level, the Ghana NCAP project was divided into two, eighteen-month phases. Mainstreaming climate change into the national development agenda was the overriding driver for both phases. Broadly speaking, the first phase focused on assessment and the second phase focused on policy integration.

Phase 1 unfolded over the period 2003 to 2006 and primarily involved the development of climate scenarios and vulnerability and adaptation assessments for the agriculture, land management, human health, and fishery sectors. Two additional policy reports were also prepared to explicitly address gaps in the GPRS; one on the nexus between climate change adaptation and poverty and another on women's vulnerability to climate change.

Activities during Phase I also addressed capacity building. During the course of activities, three capacity-building workshops were organized around training in tools for sectoral vulnerability and adaptation assessments, including poverty, gender and livelihoods linkages. By any measure, these stakeholder meetings were excellent opportunities to promote public participation and social learning, to address the effects of climate change, and to identify community-driven adaptation measures.

3.1 Climate Scenario Modeling

A climate change scenario represents a plausible future regarding temperature and precipitation regimes in response to increasing levels of greenhouse gases in the atmosphere. The difference between a reference scenario, in which the historical climate records are continued and the climate change scenario, in which anticipated trends are incorporated offers insight into the additional stresses that may adversely affect crop production, rangeland productivity, public health, and other climate-sensitive sectors.

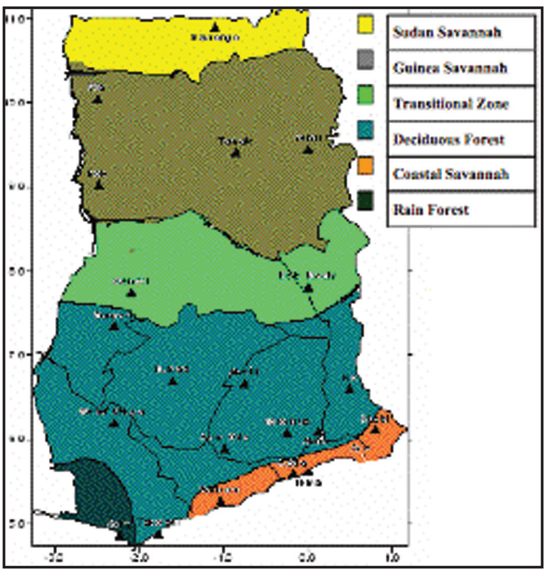


Figure 3.1: Map showing areas for which climate scenarios have been developed.

Climate change scenarios were developed for use in the assessment of the impacts of climate change in several regions as shown in figure 3.1. Climate scenarios were used in the assessment of impacts on human health, fisheries, agriculture (emphasis on root and tuber and cocoa production), and land management (including biodiversity conservation, soil erosion and desertification). Trends in the observed time series of temperature and rainfall, during the period 1961 to 2000, were analyzed and used as calibration points for the selection of particular global circulation models (GCMs) that best correlated with Ghana's historical climate patterns. After this initial screening phase, the outputs for the years 2020, 2050, and 2080 were downloaded from the MAGICC/SCENGEN1 tool for the selected models.

As shown in figure 3.2, projections of temperature and precipitation were developed for 30-year mean climates for the years 2020, 2050 and 2080. The chart on the left shows the variation in monthly mean air temperatures for Ghana as a whole. As can be seen, incremental temperatures in 2080 are expected to be the highest during the January to May period (about 4.1°C) and smallest during the summer months (about 3.5°C).

The chart on the right in figure 3.2 shows average annual rainfall for each of the six ecological zones. As can be seen, rainfall levels decrease over time for each zone. By 2080, rainfall is expected to decrease between 10% and 16%, with the steepest reductions expected in the rainforest (southwest corner) and deciduous forest (southern third) areas of the country. A number of other climate scenarios, not shown here, were developed relative to mean levels in 1990, including changes in daily rainfall levels and sea surface air temperature for coastal areas.

3.2 Vulnerability to Climate Change – Key Linkages

In order to better understand the underlying linkages between climate change and the vulnerability of key groups in Ghana, two studies were undertaken. The first focused on a review of climate and poverty links, particularly focused on rural communities; the second focused on a review of climate change issues affecting women. Both are briefly summarized in the following subsections.

3.2.1 Climate-Poverty Linkages

There is a strong relationship between climate and poverty levels. The key findings of the study showed that districts that fall within ecological zones with high temperature and low rainfall such as Sudan Savannah, Guinea Savannah and the transitional zone tend to have higher poverty incidences than those with low temperatures and higher rainfall. The ultimate effects of climate change on socio-economic or ecological systems depend on the interplay of three factors, namely, the characteristics of the climate change, the sensitivity of the system to a given change, and the capacity of the system to adapt to climate change.

Poor households tend to depend heavily on environmental goods and services. Their livelihoods are punctuated by dependence on agriculture, fisheries and forestry both of which rely on the use of land and water resources. Livelihoods depend on the capacity of ecosystems to provide the services vital for environmental balance without which food production and other productive activities cannot be carried out sustainably. The paper demonstrates that whereas poverty and climate change may appear at the extreme ends of the tunnel, the attainment of poverty reduction goals, both nationally and globally, will hardly be realized without due consideration for mainstreaming climate change into national development and poverty reduction programs.

Some of the fundamental reasons for Ghana's persistent poverty can be traced to environmental causes (see figure 3.3). For example, indoor and outdoor air pollution is a major contributor to

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1 MAGICC: Model for the Assessment of Greenhouse-gas Induced Climate Change, is a suite of coupled gas-cycle, climate and ice-melt models integrated into a single software package and SCENGEN: A Regional Climate SCENario GENerator, is used to construct a range of geographically explicit climate change projections using the MAGICC results.

poor human health. Inadequate sanitation, poor hygiene practices and lack of access to safe drinking water are major causes of diseases. Additionally, nearly a third of Ghana's population of about six million is unable to meet their basic nutritional needs, even if they were to devote their entire consumption budget to food. Climate variability will reduce food security even more because agriculture depends heavily on rainfall with few farmers using irrigation schemes.

The key finding from a detailed review of the Millennium Development Goals (MDGs), New Partnership for Africa's Development (NEPAD), and the Ghana Poverty Reduction Strategy (GPRS) is that they provide very little focus for climate change even though all documents recognize the importance of environmental health in reducing poverty. These documents poorly articulate the strong climate-poverty linkages and the recognition of a vulnerable population's need for adaptive measures. The process of integrating climate change into the GPRS is constrained by the complex cause-effect relationship between climate change and poverty and the absence of appropriate and effective data and information.

There is evidence of consistency across the GPRS and the MDGs, and in fact, the targets and indicators set up for both appear to show that meeting the GPRS goals and targets will work in correspondence with the attainment of the MDGs. The challenge here is how to overcome the assumption that meeting the GPRS targets will automatically realise the MDGs. It is one which simply goes beyond the point of integrating MDGs at the national level or into the GPRS. Insufficient attention to the practical realities on the ground, at the local level, could result in neglecting the concerns of the vulnerable and the adaptive measures that could be instituted to address their concerns.

To address these important shortcomings, a number of recommendations have been developed as briefly outlined below:

- *Deeply Involve Policy Makers:* The effectiveness of policy interventions depends on the policy makers' ability to understand and appreciate the complexities through which climate change affects the poor. It is important to deeply involve policy-makers in integrating climate change issues into national development planning, emphasizing long-term planning and the implications for poverty reduction.
- *Encourage Climate Change Research and Education:* Information and data are vital in the process of integrating climate change into national development planning. Given variations in the economic, social, and cultural contexts of affected social groups, care must be taken to avoid a "one size fits all" approach.
- *Develop Insurance Schemes:* New insurance schemes should be developed for climate-sensitive sectors such as agriculture, health, housing and infrastructure, since some impacts of climate change may be unavoidable. It will be important to adopt a "learning-by-doing" approach that starts on a pilot level at local levels, and seeks to integrate lessons learned into nationwide programs.
- *Fund Adaptation Initiatives:* A critical factor in adaptation is the availability of funds. For Ghana, it will be important that effective bilateral and multilateral strategies are put in place to mobilize funds for priority adaptation initiatives. National incentives such as tax rebates, encouraging private/public partnerships, and realignment of the national budgeting process should also be explored.
- *Strengthen Institutional & Organizational Capacity:* To promote the mainstreaming of climate change into national development, the Inter-Ministerial Committee on Poverty Reduction (IMCPR) and the Technical Committee on Poverty (TCOP) should be re-activated. It would be strategic to start with development issues that are already prominent and explore how such issues can be address in a climate-sensitive way.
- *Build and Disseminate Early Warning Systems:* Build early warning system for natural disasters and effectively disseminate these warning to stakeholders especially at the local level. Also provide efficient mechanisms for disaster management.

• *Strengthen Regional Collaborations:* Climate change issues cut across countries. Therefore, the learning of best practices and sharing of ideas and information on adaptation among countries in the sub-region should be explored using existing agencies/entities. The Ministry of Regional Cooperation and NEPAD could lead this process since they have existing collaborations with countries in the sub-region.

3.2.2 Women-Vulnerability Linkages

Vulnerability, in its entirety, reaches beyond social and economic impacts into the very foundation of sustainable livelihoods. Women, in particular, depend on local ecosystems to provide food, energy, water and medicine, and to renew fertility in soil and purity in water. In Ghana, women constitute about 51% of the total population and about 30% are heads of households according to the 2000 census. Women also control key productive sectors. They produce 70% of the country's subsistence crops, constitute 52% of the agricultural labor force, and contribute 46% of the total GDP. They play major roles in distribution and production, undertaking 85% of food distribution.

Women's roles in the society are reinforced by traditions, customs, attitudes, practices and institutional structures. In the Ghanaian system, women are the primary caregivers for childcare. In the rural areas and in female-headed households, they are also the primary managers of household resources like water, fuel and sometimes food for domestic animals. In addition to these household responsibilities, women participate in land preparation, planting, weeding, fertilizer application, harvesting and transportation of produce. They usually undertake vegetable cultivation in the dry or minor rainy season. Some women process both food and cash crops for home consumption and for sale. Given the variety of women's daily interactions with the environment, they are the social group most implicated by environmental degradation, which includes impacts from climate change.

Box 3.1: Major Socioeconomic pressures facing women

- One third of women are already living below the poverty line
- Livelihoods depend on all the sectors that are vulnerable to the impacts of climate change
- Lack of formal education
- Limited land rights
- Constrained access to formal saving and lending schemes
- Inadequate capital for expansion of economic activities

Even though women's livelihoods and their contributions towards the national economy dominate the agriculture sector, several socio-economic factors diminish women's productivity including: inaccessibility of realistic financial resources; lack of information; lack of improved appropriate technology; and unfavorable land tenure systems (see Box 3.1). Women face major challenges in the legal system too, especially with respect to land rights. Even though constitutional provisions protect women's land rights, in most parts of the country they experience discrimination under customary law.

Women in the fisheries sector are mostly on a low-income and manage large households. Post-harvest fisheries activities provide a wide range of full-time and seasonal employment to many women. The loss or decline of these opportunities through the impacts of climate change would significantly increase the risks to many women already on the margins of poverty as their income declines significantly.

The study found that women's livelihoods are also inextricably linked to adequate quality and quantity of water resources. Water scarcity has always been a potential source of social upheaval and contributes to other problems associated with climate variability such as migration from drought-affected areas. The arduous burden of retrieving and carrying water over long distances falls mostly on women and children. Particularly in the rural areas, it is the women's responsibility to make sure that there is enough water for the family to wash, cook and to support farming activities. During recurring droughts and chronic water shortages, the poor majority usually pay a high price for water, especially women and children. They pay more in cash to buy small amounts of water and they expend more in calories carrying water long distances. In the event that climate change results in flooding and other extreme weather events, the limited involvement of women and children in planning for disaster renders them extremely vulnerable.

Women and children are the most vulnerable to hunger related deaths and illness, which would be exacerbated indirectly by climate change through increased food insecurity and water shortages. Cases of cholera, diarrhea, malaria, malnutrition, and heat related deaths might increase depending on the climate scenario.

In conclusion, the two key issues that emerged from the study are women's lack of knowledge of the causes and impacts of climate change and inadequate capital for women for their economic activities. Discussions with women revealed that despite experience with climate variability and ongoing adaptation, the vast majority of women are unaware of the causes. As key stakeholders, women could enhance their roles in national development by being better informed and improving the scientific and technological basis of their livelihood activities with respect to climate change.

3.3 Vulnerability and Adaptation Assessments – Key Socioeconomic Sectors

The following subsections summarize key findings from vulnerability assessments in key socioeconomic sectors in Ghana. These sectors are public health, fisheries, agriculture and land management. A targeted list of recommended adaptation strategies is also summarized for each sector.

3.3.1 Public Health

The human health sector was selected for assessment because of its importance to the national economy and the implications for addressing poverty. Climate change, in the form of thermal stress, can directly affect cardiovascular and respiratory morbidity and mortality. Indirectly, climate variability can influence food production, malnutrition, and disease agents for vector-, water-, food-, and air-borne categories. Moreover, changes in climate can impair the efficient functioning of many ecosystems in Ghana, which in turn can have adverse effects on human health.

The key goals of the assessment were to better understand the association between climate change and human health vulnerability, investigate the consequences of climate change on the livelihood systems of poor communities, as well as provide a technical indication of the impact of climate change on human health for the following diseases: Malaria; Measles; Meningitis; Guinea worm; and Diarrhea. Adaptation options for the health sector are typically those that should happen anyway, where disease incidence is high, regardless of future predictions.

The key finding of the study is that the impact of the disease burden from projected changes in the Ghanaian climate on individuals, communities and the nation as a whole is likely to be considerable. The number of months with climatic conditions suitable for high incidence of meningitis cases will increase, bringing with it a higher risk of meningitis nationally. Diarrheal diseases are also likely to increase due to reduced rainfall and increased mean air temperatures. Less rain and hotter temperatures also increase the risk of Guinea worm infestation nationally. Table 3.1 summarizes the major public health concerns in Ghana, and how they are likely to be affected by climate change.

Regarding the relationship between health, food security and climate change, the study found that malnutrition is likely to increase due to the increased frequency of extreme weather events. Such events will reduce farmland productivity in rural areas of Ghana and by extension diminish the supply and availability of foodstuffs. Indeed, food scarcity and the corresponding increase in the cost of local foods will also be likely to lead to increased infections and absent adaptation strategies through an increase in biological susceptibility.

On the positive side, there are a few indicators that suggest that with hotter and drier conditions, there could be a decrease in the incidence of malaria and measles infection rates. This is mostly due, however, to effective case management and preventative measures that are already in place. The adaptation portion of the assessment concluded that several adaptation options will be instrumental in helping Ghanaian communities to adapt to the public health impacts associated with climatic change. Principal among them are the following:

- *Form community health groups:* This is a crucial part of the strategy as such groups would improve education that would lead to behavioral change as well as build awareness among communities of actions they could take to ameliorate risk factors in their daily living conditions. In addition, such groups could be used to promote and enforce exclusive breastfeeding for children for their first six months, and disseminate information on improved weaning practices.
- *Conduct vaccination campaigns:* The key focus of these campaigns would be on measles and meningitis as an epidemic management strategy whose objectives dovetail nicely with the role of community health groups. Health workers and health groups would also play a vital role in monitoring and communicating disease risk and strengthening nutrition and food security, both of which would build resilience and facilitate adaptation to climate change. Indeed, community groups are also well-positioned to mobilize around immunization campaigns.
- *Implement vector control:* Improved vector control was also identified as a means to breaking the transmission cycle as infection becomes more prevalent and probable. Intervention initiatives include early detection, rapid treatment, and using multiple means for disease prevention.

3.3.2 Fisheries

A quarter of the Ghanaian population lives in coastal zones and roughly 10% depend on coastal fisheries for their livelihoods. On average, 65% of the animal protein intake of Ghanaians comes from fish, giving the sector an important role in poverty reduction and food security. Fisheries also create employment opportunities and so any adverse changes in sea surface, inland water, and ambient air temperatures along the coast could dramatically affect fisheries production. For the last four decades, climatic variability has been positively correlated with fluctuations in the landings of the pelagic species upon which Ghana's fishing industry depends. Moreover, as the fishing industry in Ghana is predominantly in the hands of women, rural fisherwomen's vulnerability was a focal point for the assessment.

The vulnerability assessment was carried out using the 3-step methodology illustrated in figure 3.3. Step 1 focused on a representation of climate scenarios focusing on changing sea surface and coastal temperatures. These scenarios fed into Step 2 which applied an impact model to predict the effect of these changes in fish stock populations. Finally, Step 3 focused on understanding the perspectives of local stakeholders on the root causes of vulnerability, current coping mechanisms, and suggestions for building long-term adaptive capacity.

The key overall finding was that traditional livelihoods dependent on fisheries will be highly vulnerable to climate change. This finding is exacerbated by the fact that current fish stocks off the Ghanaian coast are already considered to be at their maximum level of exploitation.

Stakeholders identified several factors for changing trends in fish stocks. These included warmer air and sea surface temperatures (SST), over-fishing, and population growth (i.e., greater demand for fish products). Moreover, stakeholders noted that reductions in available fish stocks have led to increasing unemployment among fishermen and created serious risks to livelihoods and food security.

Table 3.1: Summary of public health impacts associated with climate change in Ghana

Disease	Baseline	Increased mean air temperature	Decreased Humidity	Decreased Precipitation	At risk populations
		Expected changes in incidence and occurrence due to climate factors:			
Malaria	Perennial in mean air temperature ranges (25.6°C to 31.1°C), thrives during high relative humidity and precipitation.	-	Down	Down	Children under 14, boys are more vulnerable than girls based on responsibilities (indoor vs. outdoor tasks)
Measles	Incidence increases from the cold dry months (Jan. & Feb.) to the hot dry months (Mar. & Apr.).	Up	Up	Up	Men and boys seem to be the most at risk. The increase is anticipated based on climatic conditions, but independent of current control mechanisms that have sent the disease into decline.
Meningitis	High numbers of meningitis cases occur in the hot dry months, the range of suitable months is increasing.	Up	Up	Up	Hot dry conditions coupled with poor ventilation favors the occurrence of meningitis cases.
Diarrhea	Diarrhea is perennial with very small monthly variation and can occur at any time of the year. Climate factors affecting the incidence and occurrence are water scarcity, poor water supply and rainfall.	-	-	Up	The most at risk group is children under 14 (boy and girls about the same); women 15-60 are much more impacted than men. The incidence of disease is more dependent on behavioral changes, poor sanitation poor disposal of feces, overcrowding, and hygienic conditions.
Guinea Worm	Low numbers of Guinea worm cases occur in high rainfall months.	Up	-	Up	The nation is at a risk of Guinea worm infestation under conditions of increased temperature and reduced rainfall amounts, but the annual distribution of Guinea worm cases showing a decreasing trend (1999-2004).

The adaptation portion of the assessment concluded that several adaptation options would be instrumental in helping Ghanaian fishing communities to adapt to the climate change impacts on fisheries. Principal among them are the following:

- *Reuse wastewater for aquaculture:* As rainfall decreases and the accessibility of freshwater declines, recycled wastewater should be used as a resource for the promotion of an aquacultural industry.
- *Restore freshwater fishery systems:* Agro-forestry and ecosystem rehabilitation at Lake Bosumtwi and in the Lake Volta Basin would build ecosystem resilience and improve the adaptive capacity of these fishery systems as the climate changes.
- *Enhance data collection and monitoring networks:* There is an overarching need for improved data quality in the fishery sector to facilitate and inform future climate change system-based fishery impact analyses.

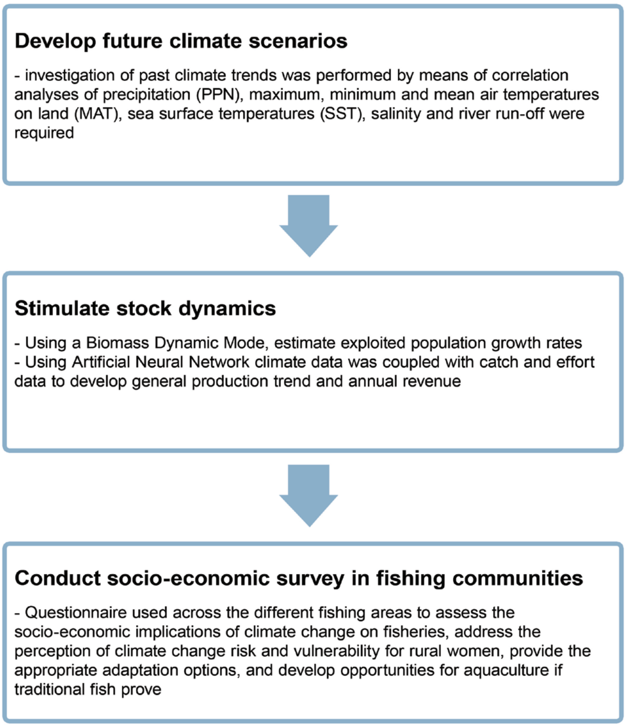

Figure 3.3: Fisheries study methodology

3.3.3 Agriculture

Agricultural land in Ghana is used mainly for production of cereal, cocoa, oil palm, root vegetables, tubers, livestock raising, and irrigated farming in conjunction with shallot farming. The vulnerability and adaptation assessment focused on a subset of these systems: root/tuber production, cocoa farming, and cereal production. The key findings for each assessment are briefly summarized in the paragraphs below.

Root crops are critical to local livelihoods and the Ghanaian economy. At present, they account for roughly 58% of per capita food consumption and about 40% of GDP. Typically, distribution and annual yields vary significantly depending on climatic conditions and the particular type of root crop. The primary impacts on the productivity of crops that do not have stable genotypes arise from water shortages, as well as harmful interactions among crops, weeds, insects, and diseases/ pathogens.

The role of cocoa in the Ghanaian economy is also substantial, particularly as a commodity export. Production increased from 395,000 MT in 2000 to about 740,000 MT in 2005 during a stretch when cocoa producer prices increased. The share of cocoa in GDP rose from about 5% in the 2000 to 2004 period to about 8% in the 2005 to 2006 period. Cocoa is highly sensitive to changes in climate. The crop is highly susceptible to drought making rainfall patterns, a primary determinant of productivity. High quality cocoa production also requires motivation, skill to employ best practices, and adaptive decision-making. Many farmers have not yet adopted the recommended best practices to mitigate the effects of climate change. This could be due in part to low incomes, low motivation, and lack of formal credit. Ill-adapted farming practices, more than any other factor, result in current high levels of vulnerability to climate change effects.

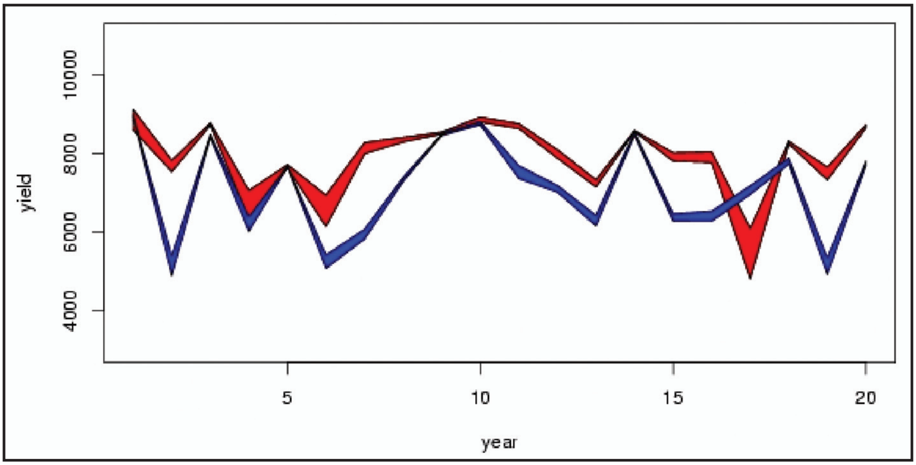

Figure 3.4: This figure illustrates a range of yields (tons/year) from a CERES maize crop model (Source: http://www.cgd.ucar.edu/asr/asr03/gsp/Image32.gif)

The NCAP project developed earlier work to assess the vulnerability of cereal production (millet, guinea corn). In 1998, the Environmental Protection Agency (EPA) commissioned an analysis of climate change on cereal production and an assessment of potential adaptation strategies. Using the climate change scenarios developed at the time and certain impact models (i.e., the CERES maize model of the CERES family of models; see figure 3.4), it was projected that maize yields would decline by about 7% by the year 2020 whilst millet, being more drought sensitive, would be largely unaffected.

The adaptation portion of the assessment concluded that several adaptation options would be instrumental in facilitating Ghanaian communities in adapting their agricultural activities to climatic change. The overriding discovery from the assessment is that effective policies could minimize adverse impacts on food security notably by reinforcing many of the existing policies and strategies as identified in the Ghana Poverty Reduction Strategy. Within this broad recommendation, specific incremental findings include the following:

- *Rehabilitate inactive cocoa farms*. Restoring degraded lands to sustainable production would build resilience in the face of climate change. Many degraded cocoa farms and forestlands that were once cultivated played important roles in reducing deforestation and migration rates, both of which actually exacerbate local vulnerability. Also, irrigation is traditionally not part of the cocoa farming systems in Ghana; however, policies to promote irrigation systems in rehabilitated farms by providing infrastructure, education and training would help farmers cope with climate change.

- *Reform financial and institutional framework for agricultural production*. The agricultural sector needs to be reformed and/or revitalized in such a way as to provide incentives for the adoption of new, more efficient farming practices. The primary means to accomplish this broad aim include enhancing farmer access to credit, stabilization of farmers' incomes through effective national pricing policies, and the development of more effective land tenure systems.
- *Promote shaded cocoa farming*. Policies should be established to encourage tree planting and maintenance of shade on cocoa farms. Shaded cocoa cropping systems are considered a sustainable agricultural practice that can provide substantial environmental benefits including habitat conservation, climate change mitigation, hydrological cycling and watershed protection. Farmers often grow cocoyam and yams alongside cocoa and new technologies in the pipeline suggest the use of cassava as shade trees in cocoa production.
- *Develop drought contingency plans*. A drought management policy should be established that makes use of information systems about changing climate conditions and patterns, advance preparatory practices, and post-drought options to deal with impacts. This would include new farm insurance programs that would help build farmers' financial resilience.

3.3.4 Land Management

Land use patterns are currently dictated by an area's environmental endowments—land is either cultivated or, if unsuitable for cultivation, it is used for pastoral purposes. Optimal land management is difficult in Ghana, hampered as it is by a lack of data for regional and local planning. Table 3.2 provides an overview of land management patterns in the region for the most recent year available, 1990.

At the broadest level, the lack of adequate land management practices has contributed towards a number of critical problems including a decline in soil quality, a reduction in biomass production, a disruption of carbon cycles, and a reduction in soil organic carbon pools. Indeed, land-degradation is considered an ongoing national threat in Ghana. Key findings showed that the situation was particularly severe in the Upper East Region (UER) where land degradation usually leads to desertification and where local vulnerability is particularly high. In the UER, more and more land is cultivated, indigenous crop varieties are nearing extinction, land is perpetually overgrazed especially under conditions of reduced rainfall, and there is a growing scarcity of firewood. Combined, these factors have led to a land degradation crisis in the region.

Table 3.2: General Land Use. Source: Ministry of Food and Agriculture

Land Use	Area ('000 Sq. km)	% of Total
Savannah Woodland	71	30
Bush fallow and other uses	60	25
Unimproved Pasture	36	15
Forest Reserves	26	11
Tree Crops	17	7
Annual Crops	12	5
Wildlife Reserves	12	5
Unreserved Forest	5	2
Total	239	100

Equally importantly, the study found that land degradation trends in Ghana are accelerating. This is true at all spatial levels—national, regional, district and farm – and is due to an overall lack of coordinated land policy and planning. Additionally, even though women contribute 80% of food production labor, insecure access to land and restricted access to credit limits the crops they can grow, discourages interest in land conservation, and encourages low productivity and food insecurity.

The adaptation portion of the assessment concluded that several adaptation options will be instrumental in helping Ghanaian communities to adapt to the impacts of climate change on land resources, as outlined below:

- *Review existing legal and institutional framework:* The Land Planning and Soil Conservation (Amendment) Act of 1957 should be reviewed regarding how well it comports with project climate change conditions. This should take the form of a comprehensive review of the structure and functions of existing land management agencies and planning of land use in Ghana.
- *Enhance options for women:* Special consideration needs to be made to improve access of women to opportunities, especially in northern Ghana. This should also include mechanisms by which women can gain access to land and credit.
- *Develop land information systems:* Zoning, mapping and production of land resource management plans should be promoted and coordinated at the national, regional and district levels in order to build adaptive capacity. Degraded lands should also be targets for inventory characterization, reclamation and monitoring to better equip land management agencies to identify where and how to implement adaptation strategies.

3.3.5 Water Resource Management

With regards to the water resource assessment, the assessment focused on the relationship between water availability, climate change, biodiversity erosion and desertification. The key findings summarized below are based upon a literature survey and broad projections of probable water future demands under climate change scenarios for the nation.

Despite the fact that Ghana has considerable surface and groundwater resources, water resources will be hit hard under climate change. Surface water resources depend on the magnitudes of river discharges or runoffs, and groundwater resources depend on recharge and capacities of aquifers. Under a changed climate, lower precipitation, enhanced evaporation, and more frequent droughts will diminish water availability in the Lake Volta reservoir. Additionally, the Akosombo dam, which typically provides about 70% of the country's energy needs, produces only 30% during periods of low water levels in the dam, posing serious implications for industrialization and private sector development.

Also, due to increasingly erratic rainfall patterns, available groundwater levels have been reduced over recent years. Water for domestic use and plant use has become scarcer due to the combined effect of declining rainfall, lowering of the groundwater table, drying streams and wells, and poor water retention capacity of the soils. Most people also have to walk for miles before they find water, especially during the dry season due to reduced rainfall. Since most farmers rely on the rain-fed agriculture (irrigation is not common in most areas), these factors also contribute to large inter-year variations in agricultural productivity.

With regards to future climatic conditions, the key finding of the assessment is the exacerbation of water supply and demand trends. On the supply side, the study found that groundwater recharge is likely to be reduced between 5% and 22% by the year 2020 and between 30% and 40% by the year 2050. This is a particularly noteworthy finding for the UER given that this region has the highest number of dams and dugouts in the country, and economic activities are increasingly related to effective utilization of this infrastructure. On the water demand side, pressures from population and a growing economy will lead to significant increases in the consumption of water. For the dry interior savanna region of Ghana, water demand in 2050 is projected to be about 12 times the current levels.

Juxtaposing the future water demand and supply findings suggests a looming water crisis for Ghana. Scarcity of water will increase the competitive pressures for basic uses of water, diminish agricultural productivity, increase the risk of water-borne diseases, and will have a negative impact on labor availability, productivity and migration.

The adaptation portion of the assessment concluded that several adaptation options will be instrumental in helping Ghanaian communities to adapt to this water crisis, as briefly outlined below:

- *Enhance rural systems for potable water and sanitation:* It will be important to develop systems to provide safe water and good sanitation in the rural areas. While this is already high among the rural development priorities of the government, the most pressing current demands in the northern drier half of the country are for safe and reliable supplies of water.
- *Implement more efficient water management practices:* The scarcity of water, particularly in the low rainfall areas, is a major factor constraining crop and animal production. The rainfall in the drier parts of the country could be more effectively utilized for intensifying the production of crops and livestock. This would involve appropriate water conservation practices, such as storage in accessible aquifers and in simple surface storage facilities such as ponds, tanks, dugouts, and small reservoirs for use in the dry months.
- *Explore implications for energy management:* Given the reliance of Ghana on hydropower for meeting electricity needs, a key recommendation is that an assessment of climate change on hydropower resources be undertaken (as discussed more fully in the section below).

3.3.6 Energy Management

Ghana's energy sector has already showed signs of susceptibility to climate change, particularly the effect of highly variable precipitation patterns on hydropower production. At present 67% of electricity generation in the country is from hydropower and 33% is from petroleum-fired thermal generation, with a small contribution of less than 1% from small-scale solar systems.

The drought of the early eighties (1980 to 1983), not only affected export earnings through crop losses but also caused large-scale human suffering and called into question the nation's continued dependence on hydroelectric power. As a result, the development of petroleum-fired thermal plants is now viewed as an energy security necessity in Ghana. By 2020, national planning calls for a more diversified energy supply system, with a larger contribution from natural gas and renewables, and possibly even nuclear power. The current rate of electrification presents the challenge of providing energy in a suitable form to a large population, primarily rural but increasingly urban, while at the same time minimizing greenhouse gas emissions.

A key finding of the review of energy supply issues is that existing renewable energy programs should be strengthened. Currently, the Ghana Renewable Energy Program promotes the development of renewable energy technologies, particularly biomass and solar energy. There has also been a Liquefied Petroleum Gas (LPG) Program since 1990 to promote the wider use of LPG instead of wood fuels to alleviate deforestation pressures.

The biomass program focuses on the development of a National Wood Fuel Policy to ensure that the production and consumption of wood fuel takes place in an environmentally friendly and sustainable manner. Such a goal overlaps nicely with adaptation priorities. Other overlapping strategies call for improved methods for charcoal and firewood production to conserve forest resources, decreased consumption of firewood and charcoal by using more efficient cooking devices, and implementing forest regeneration and afforestation programs.

Ghana receives daily solar irradiation levels ranging from 4 to 6 kWh per square meter, with cor responding peak annual sunshine duration of 1,460 to 2,190 hours. At present, direct solar radiation does not represent a major form of exploited energy in Ghana, and is currently used in niche operations mainly for crop and fish drying using traditional methods. A strengthened program for the assessment, demonstration, and evaluation of the technical, economic and social viability of solar energy technologies in Ghana, especially with regard to the development of rural communities, would be a strategic adaptation strategy. In addition, specific adaptation initiatives should focus primarily on small-scale, off-grid generation and efficiency improvements as such initiatives would lead to an improved economic situation for potential beneficiaries.

4. Key Results and Findings for Phase 2

The second phase of the NCAP effort unfolded over the period 2006 to 2008 and sought to build upon and extend the results of the first phase through a closer examination of specific adaptation options and how these could be integrated into policy and planning dialogues. Specifically, this phase focused on the identification and prioritization of adaptation options and mainstreaming these inputs into national policymaking processes. Methodologically, this was achieved through reliance on broad-based stakeholder inputs and the use of a variety of process-based tools.

Climate change related impacts do not recognize sectoral boundaries, and Ghana's traditional, sector-specific planning will be inadequate to meet future climate change challenges. The "business-as-usual" model will potentially miss both salutary and negative interactions between activities undertaken in different sectors. However, since expertise is typically localized within sectoral government offices, university departments, and institutions, a key challenge for effective adaptation planning is to make good use of this expertise while promoting cross-sector interactions. Consequently, planning for climate change adaptation in Ghana will require coordination and integration across sectors and issues. This is a key conclusion of this phase of the project.

4.1 The Akropong Approach

The goal for Phase 2 of the project was to take the conceptual outputs from Phase 1 and solidify them into a set of prioritized adaptation options that are integrated into ongoing national policy-making processes. As the project team soon discovered, this was a particularly ambitious goal given the complexity of the adaptation options themselves (i.e., technology, feasibility, management aspects) and the non-trivial institutional and ministry-specific barriers associated with their integration into ongoing policy dialogues.

The initial task in Phase 2 was to review existing development plans that had been developed by each of the affected ministries (agriculture, health, land/water). It quickly became apparent that development plans contained both maladaptive and enabling goals regarding climate change adaptation. With this starting point in mind, the research team sought to anticipate and promote positive interactions between proposed adaptation activities across different sectors, whilst seeking to minimize negative or maladaptive interactions.

To do this, the NCAP Ghana research team introduced a new approach to cross-sector project planning. Dubbed the Akropong Approach[2], it offered a conceptual framework to integrate technical inputs, financial data, and stakeholder perspectives into a unifying, consensus-building, policy-making process. At the methodological level, the Akropong Approach sought to combine several methods that have proven useful in planning activities into an integrated evaluation framework, as outlined below and illustrated in figure 4.1.

- *Logical framework analysis:* The Logical Framework Analysis (LFA) facilitates problem identification and policy planning, with an emphasis on tangible objectives with concrete indicators to measure the effectiveness of the policy. The main new element in the approach proposed in this

2 Two papers produced during the development of this methodology were 1) Prioritization of Climate Change Adaptation Options using the Cross-Sectoral Impact Analysis which describes the methodology to cross-sectoral adaptation prioritization efforts and 2) a guide for replicating the methodology entitled Planning for Cross-Sector Climate Adaptation.

paper is the modified cross-impact analysis. This approach starts with the following assumptions: a) each sector has already taken into account the interactions between its own activities when devising the sector plan; and b) many cross-sector activities do not have important interactions, and only a few should be discussed in detail.

- *Multi-Criteria Analysis:* Multi-Criteria Analysis (MCA) is then used to determine overall preferences among alternative options, where the options are intended to accomplish several objectives. Another step in the approach is scenario analysis, which includes both quantitative and analytical, and qualitative components (i.e. creative and forward-thinking description of possible future events that might affect the outcomes of the policies).

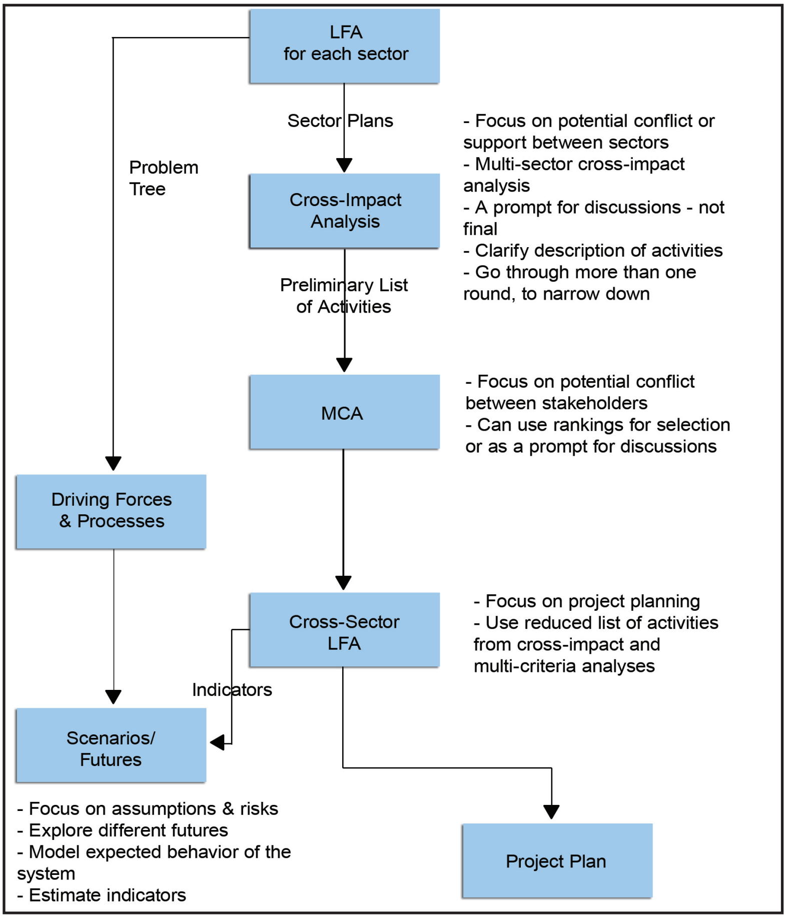

Figure 4.1: Flow of activities in the Akropong Approach

4.2 Network Building

There were a number of workshops hosted in Ghana that sought to build climate change networks both within Ghana at the Ministerial level, as well as throughout the region at the policy analysis level. The former included five Parliamentary Select Committees on Energy and Mines, Environment and Science, Finance, Legal and Constitutional Affairs, and Land and Forestry. The latter included members of NCAP country teams from Africa, the Middle East and Latin America and initiated discussion regarding linking participatory processes, vulnerability assessments, and multi-criteria analysis.

The workshops were designed around the Akropong Approach and its combined methods outlined above. These workshops included:

- Capacity building workshop on the use of analytical tools for the formulation of a national climate change strategy. (May 2007)
- Workshop on cross-sectoral impact analysis focusing on the approach to the prioritization of adaptation options. (July 2007)
- National parliamentary stakeholder forum on climate change which focused on a range of adaptation options across various vulnerable sectors in Ghana. The program received praise from parliamentarians and observer groups. (August 2007)
- National adaptation evaluation criteria development and prioritization workshop focusing on methods and tools for prioritization of adaptation options. (October 2007)

4.3 Adaptation Prioritization

The key output of using the Akropong Approach within the series of workshops described above was a nationally prioritized list of adaptation activities as shown in table 4.1. At the end of the prioritization process, there was a clear perception across the participating stakeholder groups, whatever their level (e.g. minister or farmer) or affiliation (e.g. agriculture, health) that the potential impact of climate change on Ghana's economy is a clear threat to achieving the nation's desirable development objectives.

One key conclusion of the process was that the benefit of a full cross-impact analysis is that it enabled policy-makers to identify some decisions that could deliver significant cross-sector benefits and other decisions which could limit implementation inefficiencies across sectors. Another key conclusion was that the consensus-building Akropong Approach developed by the process focus would lead to long-term benefits insofar as it laid a widely acknowledged effective marker for future discussions on the topic of climate change adaptation.

5. Lessons Learned and Strategic Recommendations

Ample evidence is now available that climate variability and climate change are having profound effects on socioeconomic development and the livelihoods of communities throughout the world. This situation has been confirmed in Ghana through the various vulnerability assessments conducted as part of the NCAP project. Indeed, Phase 1 of the project demonstrated that the overall impacts are unacceptably high for key socio-economic sectors in the country. Urgently needed are the kinds of sectoral and cross-sectoral adaptation initiatives identified through the various consensus-building activities of Akropong Approach carried out in Phase 2.

Climate change will systematically disrupt Ghanaian communities that are reliant on subsistence farming and fishing livelihoods. For farming, impacts brought on by climate change will degrade soil conditions and reduce food production. For fisheries, increased sea water temperatures will adversely impact fish stocks in coastal areas. Income from these and other economic activities will diminish, making an already severe poverty situation worse. These developments will be particularly onerous for women who lack secure land rights, access to credit, and access to other agricultural inputs and services. Strategically focusing certain adaptation innovations on women builds their individual adaptive capacity whilst facilitating their contributions towards national development and promoting national welfare.

Vulnerability to climate change reaches beyond social and economic impacts into the very nature of sustainable livelihoods in Ghana. Indeed, the study's conclusion strongly supports the existence of a strong relationship between current climate and persistent poverty levels. Under conditions of future climate change, the exacerbation of poverty conditions in Ghana could be regulated by the

Table 4.1: Prioritized climate change adaptation options in Ghana

Priority	Adaptation option	Description
1	Research & Development	• Programmatic initiatives in the evaluation of new technologies and practices to enhance productivity across each of the vulnerable sectors in the face of climate change
2	Environmental Sanitation	• Make services available and engage households in sustainable sanitation activities against a backdrop of reduced water availability
3	Awareness creation	• Education and capacity building to combat communities' ignorance of over-fishing, land degradation and climate change
4	Improved land use practices	• Use appropriate agroforestry technologies and encourage aforestation to reclaim degraded lands • Change land use activities by planting other crops such as citrus fruits, soybeans, onions, sweet potatoes and maize • Efficient land management policies that respond to increasing population and demand on land
5	Early Warning Systems (EWS)	• Build an EWS for natural disasters and effectively disseminate these warning to stakeholders especially at the local level. • Provide efficient mechanisms for disaster management.
6	Alternative Livelihood	• Supplement income with either non-farm based livelihoods or changing land-use strategies • Develop off-farm income generating activities (e.g. artisan work, petty trading , livestock and aquaculture)
7	Water resources management	• Protect watershed and conserve biodiversity • Promote central role of traditional rulers, landlords and earth priests in mobilizing communities for Integrated Water Management activities
8	Extension Services	• Make services available and engage farmers in sustained activities
9	Improved Farming Technologies	• Promote agronomic soil and water conservation measures (e.g. agro-forestry, crop rotation, tied ridging, mulching, contour vegetative barriers and improved fallow) • Promote the use of drought resistant/ tolerant and high yielding planting materials • Promote zero tillage, non-burning of vegetation, and mulching for soil moisture conservation
10	Fisheries Resources Management	• Innovate through ecosystem research to stabilize seafood, adaptive fresh water fish species and employment for sustainable livelihood • Encourage exploitation of lesser-known species to ease the pressure on the main stocks.

reform of national policymaking that focus on a range of overarching activities spanning aware ness raising, new insurance schemes, capacity strengthening, and network building.

Foremost among future activities will be the need to raise awareness among policymakers and the public regarding the impacts of climate change. While a number of strategic adaptation options have been identified and recommended for urgent action, there will be an ongoing need to fine tune the understanding of hazard locations, evolving risk factors, and acutely vulnerable communities and groups. As this information is integrated into planning and policy dialogues and the public at large – a framework for which has been successfully developed using the Akropong Approach – it will help in reducing future vulnerability by integrating actions that protect people against disease, food insecurity, diminishing water availability, and energy insecurity into strategic discussions. There will also be the continuing need to increase technical capacity through education, and training in key skills for community groups, health and other sector workers.

Finally, the manner in which adaptation in Ghana is carried out will determine the success with which the strategic recommendations are implemented. As has been discussed in the previous sections, the findings of the project strongly suggest that a more holistic approach to adaptation is needed in Ghana. There is a need for close cooperation across the affected sectors – forestry, water, agricultural, coastal zones, public health, land use planning – to ensure that every opportunity is taken to secure the overlapping and strategic benefits of adaptation initiatives and to avoid any maladaptive or zero-sum results. Considering the uncertainties that still surround many of the key findings offered in this report, such policies should be flexible enough to adapt to any future changes in resource, market and climatological conditions.

Annex: List of Technical Reports Prepared

Phase 1:	Phase 2:
• Phase 1 Workplan • Output 1: Human health vulnerability assessment • Output 2: Fisheries vulnerability report • Output 3: Land management report • Output 4: Agriculture report on cocoa • Output 5: Agriculture report on tubers • Output 8: GPRS and climate change linkage paper • Output 9: Women and climate vulnerability paper • Final Progress Report • Progress Report 1 • Progress Report 2	• Phase 2 Workplan • Output 1: Composite Report - William Kojo Agyemang-Bonsu, et. al.: Ghana's Climate Change Impacts, Vulnerability and Adaptation Assessment, May 2008 • Output 2: Workshop report on discussion of Policy goals and criteria (LCA, MCA, scenario analysis) • Output 3: Workshop report on quantitative scenario development and results • Output 4: Report on the methodology detailing approach to stakeholder engagement and the development of evaluation criteria • Output 5: Report on the methodology detailing approach to adaptation policy prioritization • Output 6: Report on the national adaptation policy strategy in Ghana • Output 7: Synthesis report of Phase II • Progress Report 1 • Progress Report 2

Finding Points of Engagement to Introduce Climate Change Adaptation into Water Management Planning: A Synthesis of NCAP Activities in Guatemala

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1. Introduction

The impression of Guatemala as viewed from space is that it, along with its neighbors in Central America, is relatively green and verdant. This view does not conjure up the immediate image of water as a constraining factor in livelihood generating activities pursued by the population. This perspective, however, does not reveal the extent to which Guatemala is dependent on a natural resource based economy, and in particular the agricultural and forest management activities in which a significant proportion of the population is engaged. The productivity of these activities and their potential to support, and even enhance, the livelihoods of a largely rural population are dependent on climate and the associated hydrological response. Although it is a relatively small country, with a surface area of 108,890km^2, the geography of Guatemala creates strong spatial variations in climate across the national territory, to which local resource based economic activities are attuned. Production systems and livelihood generating activities can vary across very small distances, many of which are exposed to climate related risks. In addition, many of these risks, such as flooding, are exacerbated by heavy exploitation of the land base. Thus, Guatemala is an appropriate venue for studying the threat to sustainable water management posed by climate change and possible adaptation options.

For this reason Guatemala was selected as one of 14 countries across the globe to participate in the Netherlands Climate Assistance Project (NCAP). This five year study sought to achieve several objectives, among them:

- The creation of capacity in the developing world to recognize the threat posed by climate change, and to evaluate adaptation options;
- The integration of climate change considerations into national economic development and poverty reduction planning, primarily through a focus on important livelihood generating activities; and
- The development of a community of professionals around the world who can share experiences on climate change adaptation.

Running through these objectives is a desire to document the important lessons learned in each of the 15 partner countries during the NCAP project so that that the knowledge and insights gained can be shared with others confronting the challenge of adapting to climate change. This paper attempts to synthesize a set of insights from the work that has been completed in Guatemala.
In this regard, the primary lessons learned pertain to assessing the appropriate points of engage-

ment for introducing climate change considerations into policy setting and decision making processes. These lessons emerged from the fact that the NCAP implementation team made very intentional attempts to bind their work to such processes throughout the life of the project, to varying degrees of success. The evolution of the level of interest in NCAP activities among participants in the policy and decision making processes as the study progressed, is potentially instructive to others seeking to introduce climate change considerations into national development and poverty reduction plans. Although the focus of NCAP activity in Guatemala was on the water sector, and as such much of the information presented here will be relevant to water resources, the paper attempts to construct a general structure for successful engagement with policy makers and decision leaders on the issue of climate change adaptation.

2. The Guatemala Context

Guatemala, home to 13,002,206 inhabitants, is the most populated of the Central American countries. With a per capita GDP of US$4,700 per year, it has an economy roughly one-half the size of that found in Argentina, Brazil, and Chile. Since the cessation of civil unrest in 1996, and the initiation of the current period of political stability, economic growth has been steady and in 2007 was estimated to be 5.7%. The composition of the economy by sector, estimated to be 13.2% from agriculture, 25.9% from industry, and 60.8% from services, suggests that natural resource based livelihood generation is only of marginal importance to the people of Guatemala. Several additional factors counter this perception.

Firstly, two large components of the industrial sector are sugar processing and furniture manufacture, both of which are strongly natural resource dependent. Secondly, two-fifths of national exports are agricultural products, with coffee, sugar and bananas representing the main products. Thirdly, in terms of labor allocation between economic sectors 50% of the labor force is involved in agriculture. This contributes to a fourth critical factor, that 56% of the population in Guatemala falls below the poverty line. Taken together these figures suggest that any national development and poverty reduction plan for Guatemala must focus on individuals involved in natural resource based livelihood generating activities. For these individuals, water, defined both by the timing and quantity of availability and by its quality, is a critical resource. It was this assessment that led the NCAP implementation team in Guatemala, the Programa Nacional de Cambio Climatico (PNCC), to focus its NCAP supported activities on the potential link between climate change and water resources, and the implication of this link for efforts to improve the standard of living for the poor.

a. Climatic and Hydrological Setting

Guatemala's geography has a determining effect on climate and hydrology in the various regions of the country. Two factors, the distance to the ocean and positions relative to prominent mountain ranges that create a Continental Divide, contribute in large measures to spatially varied climatic conditions (figure 1). Typically the coastal areas are wetter and cooler while interior zones located behind major mountain ranges, the highest of which in the southwest rise to over 3,000m, are hotter and drier. Guatemala is also located well within the typical path of tropical storms affecting the Caribbean Sea and the Eastern Pacific Ocean and can experience extreme precipitation events, which are typically strongest at the point of landfall and dissipate as they move inland. Annual patterns of precipitation in Guatemala are also influenced to a large degree by the pattern of the "El Nino" and "La Nina" ocean temperature oscillations in the eastern Pacific.

The geography of Guatemala also plays a strong role in the distribution of watershed and catchment areas within the country. The map in figure 1 shows the boundaries of the major national watershed areas within the limits of the national territory (some of the watershed areas are shared with neighboring countries). What is most striking is the difference in size and shape between the band of relatively narrow watershed areas that descend from the Continental Divide to the Pacific Ocean in the southwest and the larger watershed areas that traverse the more tropical plains to the north and east.

Figure 1: Relief Map of Guatemala

Other features in figure 1, particularly the concentration of cities and the density of the road network, reveal that most of Guatemala's population is found in the southern portion of the country. In this region, it can generally be stated that watershed areas draining towards the Pacific experience higher levels of precipitation, while those draining towards the Caribbean are drier. This suggests that in order to explore the link between climate change, water resources and livelihoods, due consideration would have to be taken of this hydrologic spatial variability.

b. National Climate Change Program

The PNCC is a program within the Environment Ministry of Guatemala, and was created in part to coincide with the preparation of the 1st National Communication under the United Nations Framework Convention on Climate Change (UNFCCC). The PNCC is charged with assessing the risks of climate change in Guatemala and recommending steps the government can take to reduce the country's vulnerability to these risks. Soon after its creation, the PNCC played a central role in preparing Guatemala's 1st National Communication, which concluded that the country is vulnerable to both current climatic variability and anticipated climate change. The communication also identified what were perceived to be the most vulnerable sectors, which included: public health; forest resources; cereal production; and water resources.

This assessment supported a conclusion drawn by the PNCC, namely that hydrology and water management were integrated themes across these sectors. They impact public health in terms of reliable access to clean potable water. They impact forest management and cereal production through the provision of soil moisture to promote biomass production and are impacted by these sectors in terms of the role they play in watershed areas' hydrological processes. As such, following the publication of the 1st National Communication, the PNCC made an early decision to focus much of its energy and resources on better understanding the link between climate change and water resources.

As part of this effort, the PNCC participated in a previous project funded by the United Nations Development Program, *Fomento de las Capacidades para la Adaptación al Cambio Climático en Centro América, México y Cuba* (Building Capacity for Climate Change Adaptation in Central America, Mexico, and Cuba). Based on activity undertaken as part of that project, the PNCC produced a report entitled *Síntesis de Vulnerabilidad Futura, Propuesta de Medidas de Adaptación y Estrategia de Adaptación al Cambio Climatico* (Synthesis of Future Vulnerability, Proposal of Adaptation Measures, and Strategy for Climate Change Adaptation) which included a long list of potential water management adaptation strategies. These strategies were divided into five categories: flood prevention; flood management; flood rehabilitation; drought management; and drought rehabilitation. This list of possible adaptations served as a starting point for the activities pursued under the NCAP project.

3. Selection of River Basins

Specifically, the goal of the NCAP activities was to investigate whether consideration of the proposed adaptation strategies could be integrated into ongoing water management policy settings and decision making processes in Guatemala. While there is a loose national context for many of these processes, Guatemala's constitution states that the country's water resources belong to the people and there is little national water planning infrastructure. Guatemala's legislators have tried unsuccessfully three times to pass a comprehensive water law and the most recent attempt in 2005 reached impasse in Congress. As an intermediate solution, a newly formed water resources and basins' unit within the Environment Ministry was administratively charged with the difficult task of formulating Guatemala's national water policy as it is to be applied under water management policy setting and decision making. This unit, referred to as the Unidad de Recursos Hídricos y Cuencas (Basins' Unit) will need to coordinate with other water focused programs housed in other ministries in Guatemala in order to arrive at a coherent national strategy.

In the meantime, important water resource management planning in Guatemala is occurring at the local watershed area level. In fact, it is likely that the Basins' unit will ultimately opt for decentralized basin oriented water management institutions as a central component of the eventual water planning infrastructure. As such the PNCC felt that it was reasonable to focus its NCAP analysis on the watershed area level. Furthermore, in light of the hydrological variability across the Continental Divide, the PNCC decided to select one target watershed area draining towards the Pacific Ocean and one draining towards the Caribbean Sea. The Rio Naranjo (Pacific) and the Rio San Jose (Caribbean) were selected.

a. Rio Naranjo

The Rio Naranjo watershed area flows (figure 2) southwest from the Continental Divide in a region close to the border with Mexico. The change in elevation between the headwaters and the water at the mouth of the river is 3,322m which is distributed over the river length of 104km. The overall 3.4% grade makes this a fairly steep, high energy system, particularly in the headwater region. Torrential flooding during large storm events is a very real concern. During dry periods, however, water scarcity can be an issue as is water quality owing to a near complete lack of wastewater treatment infrastructure in the basin. With a total area of 1,255km^2, the watershed area covers 1.16% of the national land mass.

b. Rio San Jose and Rio Shutaque

The Rio San Jose watershed area (figure 3) is located in the southeastern portion of Guatemala at the low end of a series of mountain ranges that cover the southern portion of the country. The

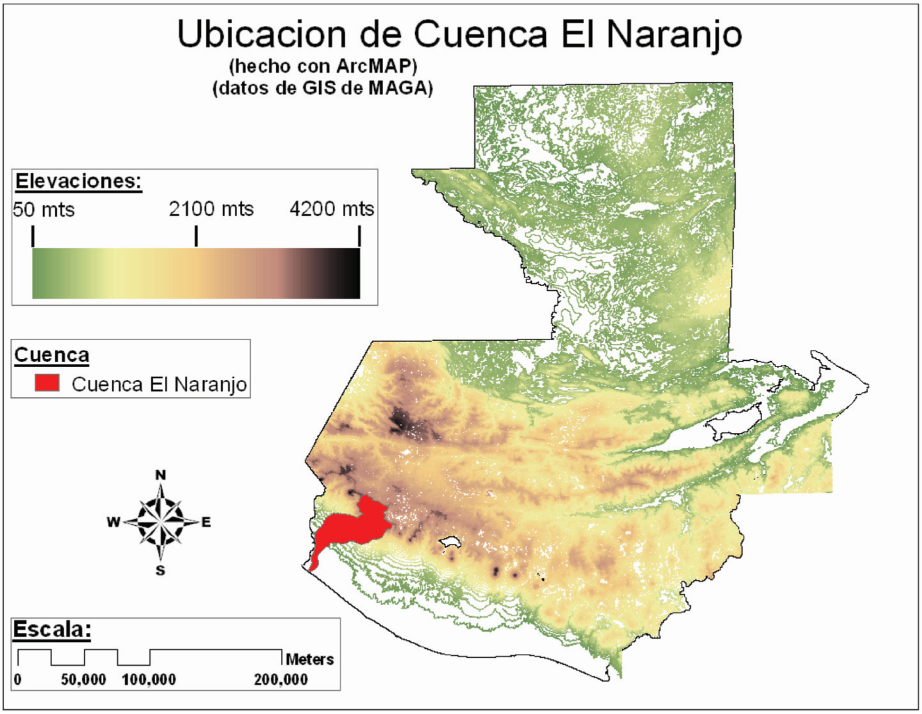


Figure 2: Location of the Rio Naranjo Watershed Area

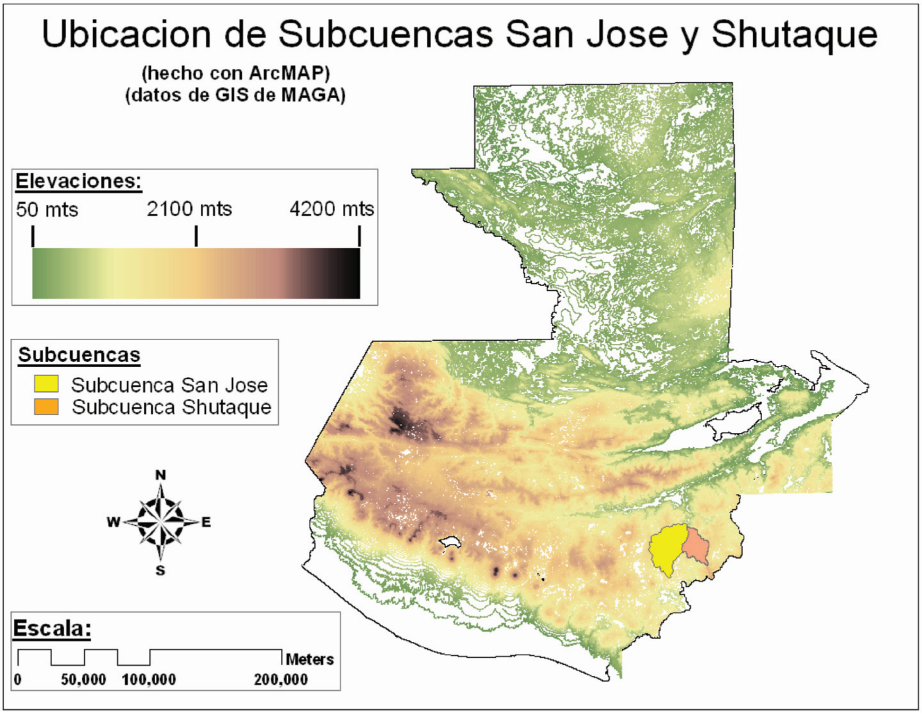


Figure 3: Rio San Jose (yellow) and Rio Shutaque (orange) Watershed Areas

headwater region of the watershed area, at an elevation of 1,820m above sea level is substantially lower that the Rio Naranjo, and the elevation at its mouth is 350m above sea level. After selecting the Rio San Jose as the second target watershed area, the PNCC decided to add the adjacent Rio Shutaque watershed area to the analysis as a water transfer towards the Rio San Jose watershed area is under consideration. Taken together, the Rio San Jose and Rio Shutaque watershed areas constitute 0.9% of the total Guatemalan land mass. Water scarcity is the main water management concern in these watershed areas.

4. Inventory of Water Management Planning Processes

In the absence of a clear national framework for water resource management and decision making into which climate change adaptation considerations could be introduced, the PNCC chose instead to analyze Guatemala's ongoing, somewhat ad hoc, water policy setting initiatives in order to determine where it would make the most sense to introduce a discussion about climate change adaptation. In preparation for this process, the long list of potential climate change adaptation strategies presented in the *Síntesis de Vulnerabilidad Futura, Propuesta de Medidas de Adaptación y Estrategia de Adaptación al Cambio Climático* were collated according to their relevance to four general types of water management policy dialogues currently underway in Guatemala. These are:

1. Agricultural policy designed to promote agro-silvo-pastoral productivity;
2. Watershed area management policy to reduce flood risk and improve water quality;
3. System investment/operation policy to reduce flood risk and improve water quality;
4. Integrated Water Resources Management promotion for equitable water allocation.

Based on connections within the national government, the PNCC was aware that agents of the following organizations, working at both the national and local levels, were active in these policy dialogues. Guatemala's Agriculture Ministry (MAGA) oversees irrigation and researches farming and crop productivity with emphasis on soil conservation and crop productivity. Guatemala's National Forestry Institute (INAB) works to prevent deforestation through its *Programa de Incentivos Forestales*. Guatemala's National Disaster Planning Network (CONRED) is made up of various institutions that have an interest in preventing damage from storms, floods, forest fires, droughts and other natural disasters. As previously mentioned, the new basins' unit within the Environment Ministry is charged with water and wastewater planning and monitoring, and is an advocate of the IWRM.

Working through agents in these organizations, research was conducted in the Rio Naranjo and Rio San Jose/Rio Shutaque systems in order to identify an appropriate audience for the water management adaptation analysis that was planned for the NCAP project, which would follow the analytical process illustrated in figure 4. The basic structure of this framework is a four-step process:

- Step 1: Understand the implications of the general circulation models (GCM) of the global climate system for the climate in a particular region of the world.
- Step 2: Deploy appropriate techniques to downscale possible regional climatic predictions to climatic time series representative of possible future conditions in watershed areas of interest.
- Step 3: Evaluate how changes in the climate in these watershed areas will alter the local terrestrial components of the hydrological cycle, in particular streamflow, aquifer recharge and evaporative water demand, which are the types of flow that are typically managed.
- Step 4: Assess how water systems dependent on these flows will perform under anticipated patterns of change, and evaluate management options to ensure the long-term performance of the water system in the face of these changes.

Here it should be pointed out that the framework, which emerged from academic and applied research on how to implement a climate change adaptation analysis for the water sector, was

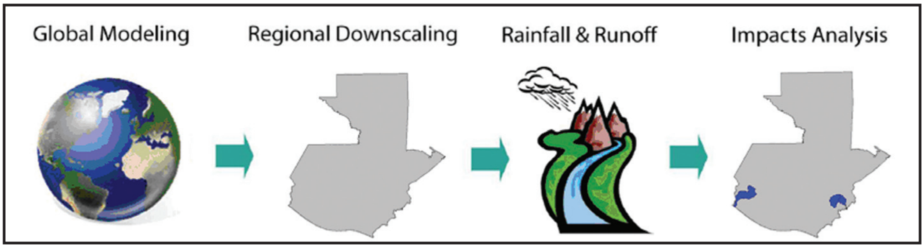


Figure 4: Proposed Water Sector Climate Change Adaptation Analytical Framework

presented to participants in the policy dialogues as an appropriate starting point. The selection of the target watershed areas was also presented as an appropriate place to start from.

In retrospect, it may have been better to engage the participants in the target dialogues for the development of the analytical framework, particularly in terms of creating a sense of ownership of the analysis and assuring its relevance to the particular process. A common reaction among stakeholders was that this approach was quite technical and that it may be difficult to implement in a data limited setting such as Guatemala. The other side to this argument is the fact that the framework represents the best accumulated knowledge on this subject. This dilemma has implications for the question of the appropriate point of engagement for the introduction of climate change information into a discussion on policy setting.

5. Possible Points of Engagement

Based on the experience of interacting with participants in policy setting processes in the target watershed areas from early on in the NCAP project, it became clear to the PNCC that there are at least three important points of engagement between the climate change adaptation community and water management planning and decision making.

a. Awareness Raising

The first point of engagement with an ongoing water resource policy setting process is simply to create awareness that the changing climate and associated changes to hydrological regimes could be an important factor to consider in arriving at a final policy or decision. This point of engagement typically provides several hurdles that can be a challenge to overcome. The first relates to lingering doubts among some stakeholders that climate change is really happening. The second is the perception that while it may be happening, it is too far off in the future to be of concern to the issues at hand. The third hurdle, which is perhaps the most difficult to overcome, is a belief on the part of one or several stakeholders that while climate change is happening, taking it into consideration is likely to reduce the justification for their preferred resolution of the decision making process in question.

b. Impact Assessment

The next possible point of engagement would be to actually try to understand the potential impacts of climate change on some key factors in the decision making process. These might include streamflow, water quality, evapotranspriation rates, aquifer recharge rates, reservoir storage, water supply reliability, indeed any number of water related factors. Obviously quantifying these impacts requires some analysis beyond simply inferring what higher temperatures or reduced rainfall may mean in terms of the future evolution of a particular factor. At this point of engagement, two hurdles are prominent. The first relates to a suspicion that any quantification of future impacts is too uncertain to be useful to the current decision making process. The second hurdle is more subtle and it relates to the fact that the water related factors analyzed in terms of their future evolution under conditions for climate change need to be considered relevant by those involved in the decision making process.

c. Defining Appropriate Adaptation Strategies

If relevant, potential impacts of climate change, properly characterized in terms of their uncertainty, are developed it becomes possible to begin an exploration of available adaptation strategies. This is the third possible point of engagement identified by the PNCC team. Activity at this level includes defining a series of strategies that could help overcome relevant, potentially negative impacts associated with climate change. Here again there are two primary hurdles that must be overcome as part of the effort to introduce climate change considerations. The first relates to the fact that participants often cling to their own preferred understanding of the process, as it is difficult to fully discount their strategy in the face of the uncertainty associated with climate change impacts analysis. The second hurdle is that climate change may require participants in a particular decision making process to imagine adaptation strategies that fall outside the range of strategies that have typically been considered. This is a difficult intellectual challenge.

6. Building Analytical Tools

In order to implement the analytical framework shown in figure 5, models of the Rio Naranjo and Rio San Jose/Rio Shutaque systems needed to be constructed. These models run using future climatic time series constructed based on output from the GCMs, they assess how hydrological processes in the target watershed areas will change under alternative future climatic conditions, and they simulate the performance of the installed water management system under this future hydrological regime. In order to construct the required models, the PNCC selected the Water Evaluation and Planning (WEAP) system developed by the Stockholm Environment Institute (SEI) as a modeling platform. The following section presents the platform and the process that was used to build, calibrate and run the WEAP applications developed for the target watershed areas.

a. The WEAP platform

The WEAP platform is a graphical software system in which a user assembles a series of model objects corresponding to the physical elements of a water system such as watershed areas, rivers, aquifers, reservoirs, diversion works and transmission links. These objects are characterized based on relevant available data. The WEAP user then defines a policy context, including the priority assigned to different water uses, the preferences between various supplies, and required flows in rivers and streams, within which the physical elements are arranged. This is done over a past time period so that the model can be calibrated to ensure that it provides a reasonable representation of the water system in question. The WEAP can then be used to construct "what if" scenarios about the future whereby critical system elements are varied. As an example, consider the following sequence of scenarios relevant to investigating water sector adaptation to climate change:

1. Current climate, watershed area conditions, infrastructure, and operating rules continue into the future in the face of increasing water demand.
2. In addition to increasing water demand, hotter and drier climatic conditions will change watershed area conditions, while infrastructure and operating rules continue.
3. In the face of these change, efforts are made to:
   a. Rehabilitate degraded watershed areas; and/or
   b. Change rules governing the operation of the current infrastructure, and/or
   c. Add new infrastructure.

Scenario 1 is classic water planning, scenario 2 is a climate change impact assessment, and scenario 3 is a climate change adaptation study. Work with the WEAP in Guatemala has moved through each of these steps.

b. Data Collection and Preparation

In spite of the perception that the availability of data is a limiting factor in the development of modeling tools such as the proposed WEAP applications, the PNCC succeeded in assembling all of the critical data through a process of outreach to the various institutions with relevant data in Guatemala. Given the current urgency around climate change in both the media and in political circles, a data request to work on climate change impact assessments and adaptation studies proved attractive. The PNCC was also assisted in the data collection effort, no doubt, by its well established connections with the government agencies working on some aspect of water management.

One of the critical data sets to acquire related to the recorded observations of streamflow within the target watershed areas. In the Rio Naranjo, data sets for six gauging stations were acquired, while information for five stations was available in the Rio San Jose/ Rio Shutaque system. Tables 1 and 2 summarize the period of record for these stations. Clearly, data from these stations is not continuous, and closer examination of the data conducted by the PNCC suggested that some of the records are of inadequate quality. Nonetheless standard hydrograph reconstruction techniques were used to develop streamflow time series for these stations which were deemed sufficient for the task at hand.

Table 1: Streamflow Records for the Rio Naranjo Watershed Area

		1970										1980										1990										2000			
CLAVE	**NOMBRE**	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3
130601	COATEPEQUE	=	=	=	=	=	=	=	=	=		=	=	=																		=	=		
130701	CHUVA						=	=	=	=	=	=																							
171401	MELENDREZ	=	=	=	=																														
171403	MELENDREZ II				=	=	=	=	=	=	=	=	=	=	=																				
171402	PAJAPITA		=	=	=	=	=	=	=	=	=	=				=	=	=														=	=		
172301	CORRAL GRANDE	=	=	=	=	=	=	=	=	=		=	=		=	=																=	=	=	

Table 2: Streamflow Records for the Rio San Jose and Rio Shutaque Watershed Area

		1960										1970										1980										1990										2000				
Clave	**Estación**	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4
	Vado Hondo																																										=	=	=	
40101	Petapilla																											=	=	=	=	=	=	=	=	=	=	=	=	=			=	=	=	
40201	Camotán										=	=	=	=	=	=	=	=	=	=	=						=												=		=	=		=	=	
40202	Copán																									=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	
100202	Volcán Ipala														=	=	=	=	=	=	=	=	=	=																						

Having acquired these streamflow records, locations of the gauges were used as a point for the definition of sub-watershed areas within each of the target watershed systems. Sub-watershed areas were necessary because it was the water from the point of outflow from a defined stream catchment that the WEAP rainfall runoff model needed to complete step 3. Without sub-watershed areas, the only place that these factors could be defined would be at the final point of discharge from the larger watershed area. Within each sub-watershed area, theWEAP applies a climate time-series appropriate for that particular portion of the larger watershed area.

The PNCC was able to secure from the Ministry of Agriculture, GIS data sets on land use and land cover in 2001 for the target watershed areas. These are shown in figure 5. Whilst the land use patterns in the Rio Naranjo system reflect a diverse agricultural economy with coffee, beans, palm oil, pasture, rice, vegetables and fruit all being produce, the Rio San Jose and Rio Shutaque system, outside the zones covered by forest, is dominated by forage pasture and to a lesser extent beans.

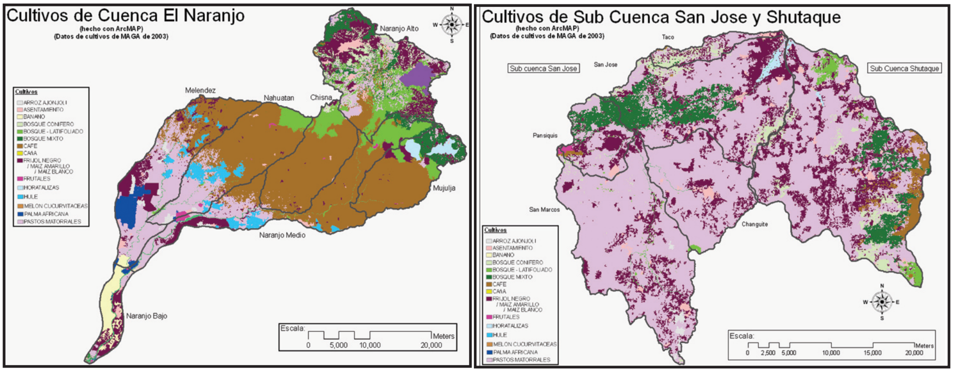


Figure 5: 2001 Land Use/Land Cover in Sub-Watershed Areas of the Rio Naranjo, Rio San Jose and Rio Shutaque Watershed Areas

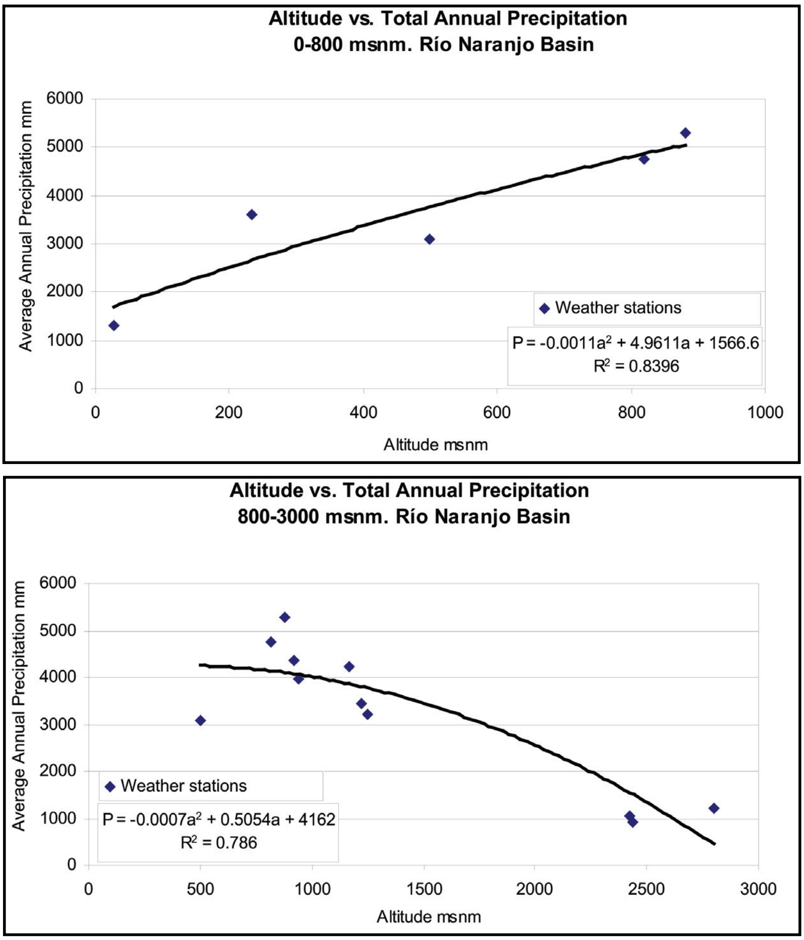


Figure 6: Relationship between Average Annual Precipitation and Elevation in the Rio Naranjo Watershed area

Coffee and fruit production are limited to the relatively high elevation margins of the watershed areas.

The differing nature of land use patterns in these two systems is largely explained by differences in climate, figures 6 and 7 present the relationship between elevation and average annual precipitation for the two watershed areas derived from monthly climate station data acquired from INSIVUMEH, the meteorological service of Guatemala. The first thing to observe from these figures is the maximum annual precipitation in the Rio Naranjo system, occurring at an elevation of approximately 1,000m above sea level (ASL), is close to 5,000mm/year. In the Rio San Jose system the maximum average annual precipitation level is closer to 1,000mm/year while in the Rio Shutaque system the figure rises to approximately 1,400mm/year. In all of the systems there seems to be a pattern whereby the average annual precipitation depth reaches its maximum value at an elevation of approximately 1,000m ASL, at which point it declines with increasing elevation.

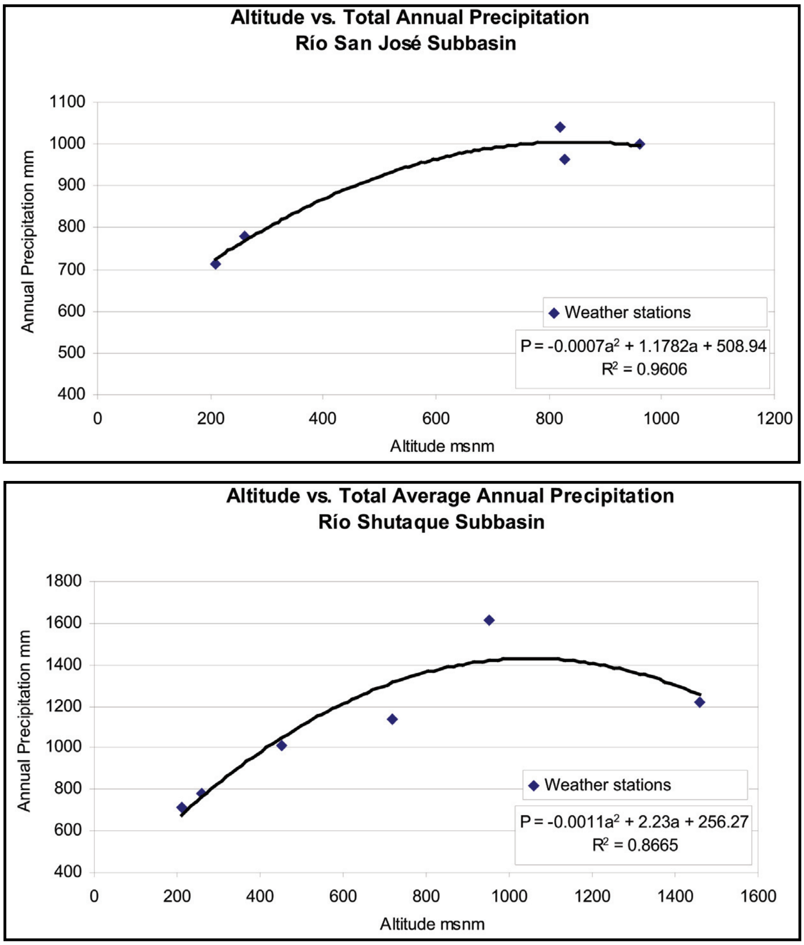
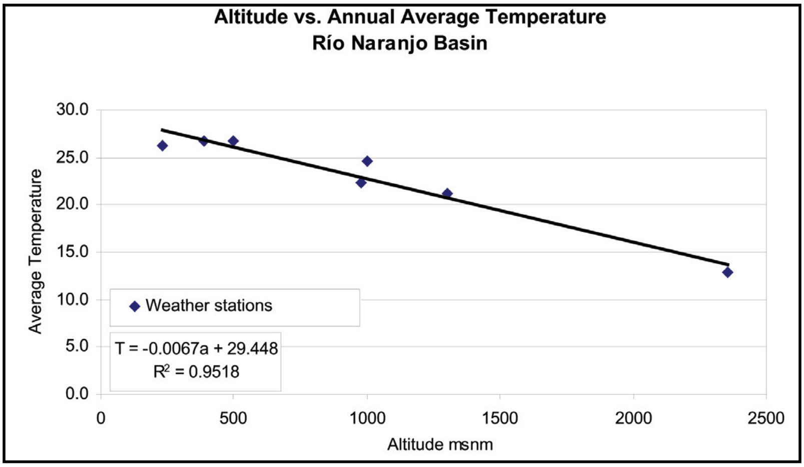
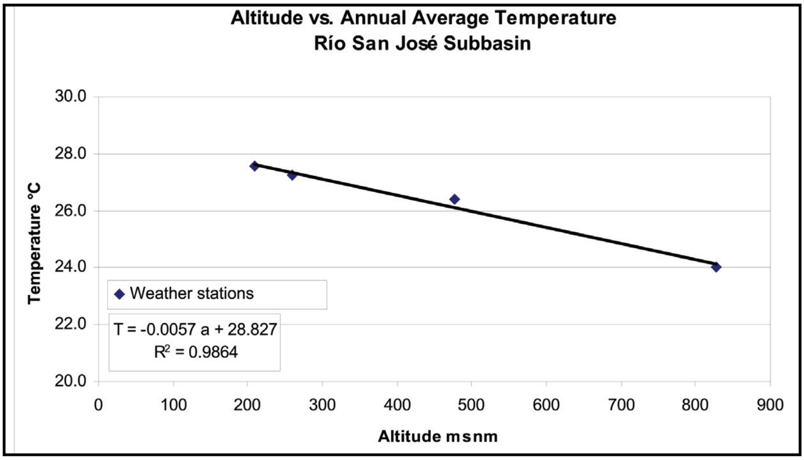


Figure 7: Relationship between Average Annual Precipitation and Elevation in the Rio San Jose and Rio Shutaque Watershed areas





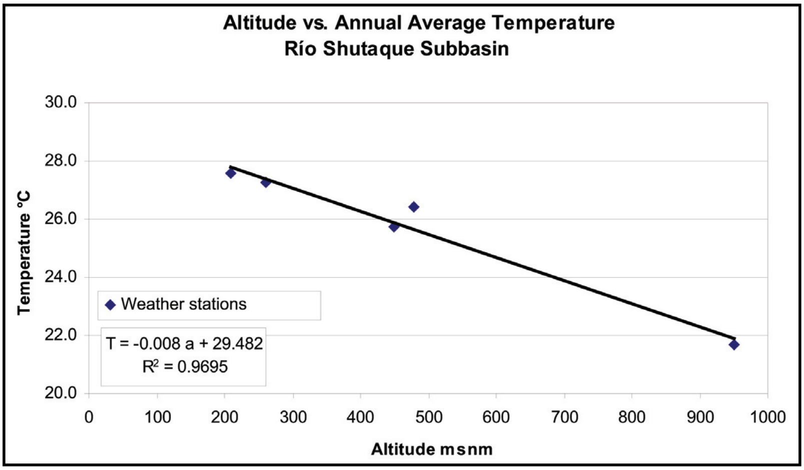


Figure 8: Relationship between Average Annual Temperature and Elevation in the Rio Naranjo, Rio San Jose and Rio Shutaque Watershed areas

In terms of air temperature, available time series of monthly values where processed in order to develop a relationship between the average annual temperature and elevation. Values for the two target systems, the Rio Naranjo and the Rio San Jose/Rio Shutaque, are shown in figure 8. Visual analysis of these graphs suggests that the target systems are not dramatically different in terms of their temperature profiles, the major difference being that as the Rio Naranjo system rises to higher elevations, it has areas with lower average temperatures than those observed in the Rio San Jose/Rio Shutaque system. It is in these cooler, high elevation zones that much of the diverse agricultural production in the Rio Naranjo system takes place.

In addition to data on land use and land cover, the PNCC team acquired data from the Instituto Nacional de Estadística (INE), the National Census Bureau, on the number of inhabitants living in each of the target systems. In 2001, a total of 335,883 inhabitants were living in the Rio Naranjo watershed area, whilst a total of 111,235 resided in the Rio San Jose/Rio Shutaque watershed area. The spatial distribution of these populations is shown in figure 9.

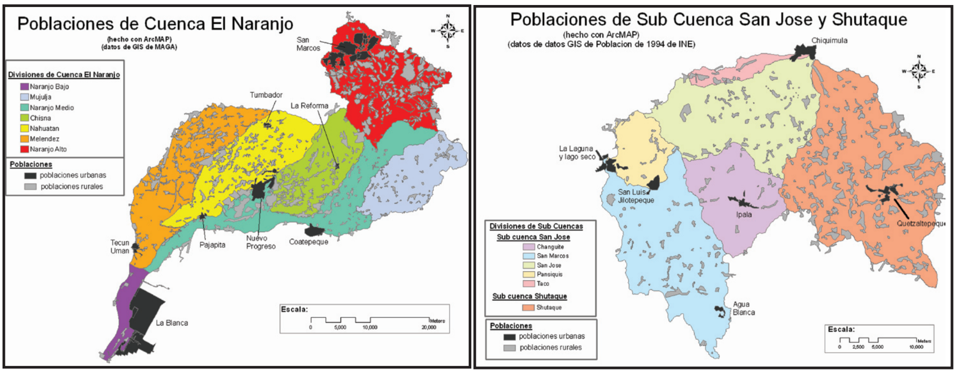


Figure 9: Spatial Patterns of Human Settlement in the Rio Naranjo and Rio San Jose/Rio Shutaque Systems

This figure differentiates between those individuals living in towns and cities and those residing in rural communities. In the Rio Naranjo system, approximately 230,000 people, or 68% of the population, were living in rural communities. The largest urban center was San Marcos with a population of approximately 46,000 inhabitants. In the Rio San Jose/Rio Shutaque system the rural population in 2001 was 65,770, or 59% of the total, with the largest city Chiquimula supporting 27,040 inhabitants.

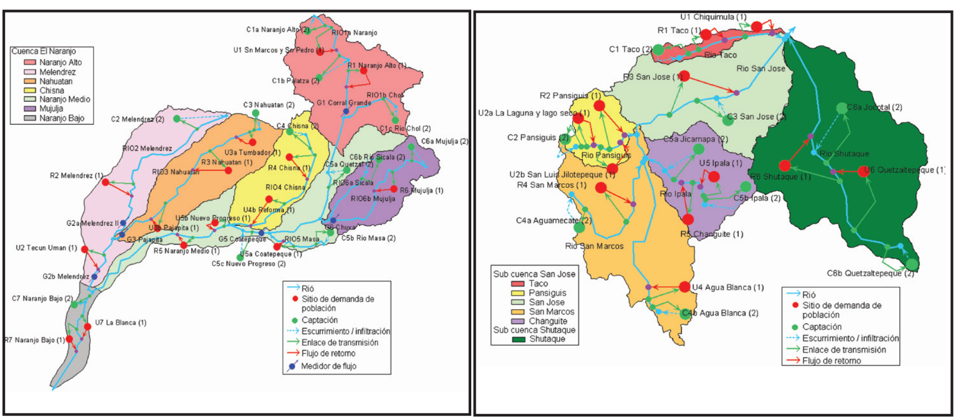


Figure 10: WEAP Application Schematics of the Rio Naranjo and Rio San Jose/Rio Shutaque Systems.

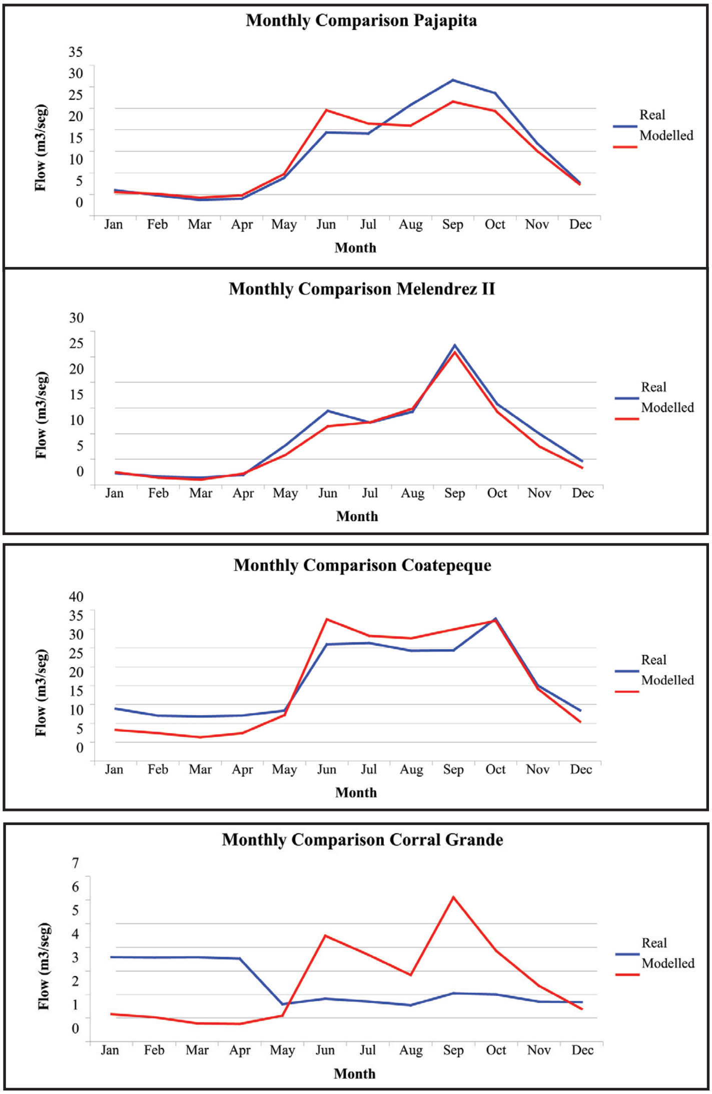


Figure 12: Streamflow Calibration for the Rio Naranjo System

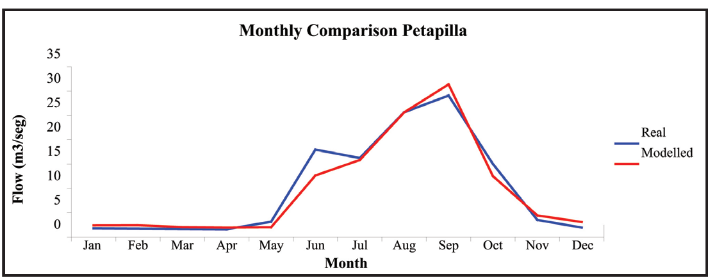


Figure 13: Streamflow Calibration for the Rio San Jose/Rio Shutaque System

c. Model Building

Having assembled and processed all of this data, the PNCC team turned its attention towards using it to build WEAP applications of the two target systems. These are shown in figure 10. A key feature of these applications is the various sub-watershed areas located upstream from the identified gauging stations. Within each sub-watershed area, two demand points (red dots) are identified; one is associated with the urban population in the sub-watershed area and the other associated with the rural population. Based on available data, urban inhabitants were assigned a slightly higher per capita water consumption rate. Green dots within each sub-watershed area contain information on the land use and land cover distribution within each sub-region and the climate time series that is applied for that particular zone. This information is used to simulate rainfall runoff processes. Other objects on the schematics represent the elements of the installed hydraulic infrastructure.

d. Model Calibration

Using these WEAP applications, run using climate time series constructed from the data presented in figures 6, 7 and 8, the models were calibrated so that the simulated streamflow values at the outflow point of each sub-watershed area reasonably matched recorded time series reconstructed from the record available at the gauges presented in tables 1 and 2. This was achieved by adjusting, within what were considered to be physically reasonable limits, a series of model parameters that control the simulation of rainfall-runoff processes in each zone:

- Root Zone Water Capacity
- Deep Water Capacity
- Deep Conductivity
- Surface Runoff Resistance
- Root Zone Conductivity
- Preferred Sub-Surface Flow Direction

Having settled on what was deemed to be an acceptable set of parameters, a final comparison between monthly simulated streamflow values and observed values was carried out. Figure 11 shows the comparison for points in the Rio Naranjo system and figure 12 shows the comparison for the Rio San Jose/Rio Shutaque system.

e. Climate Scenarios

The next step in the implementation of the analytical framework shown in figure 4 was the construction of downscaled climate time series for two target systems. There is still a great deal of scientific debate regarding the best methodology for transforming the information from the GCMs into something that can be used to carry out rainfall-runoff analysis at the watershed area scale. The PNCC chose to implement a "book-ending" approach whereby information from both pessimistic and optimistic GCMs was transformed for use in the Rio Naranjo and Rio San Jose/Rio Shutaque WEAP applications. The starting point for this analysis was to define the range of potential climatic conditions in 2050 in the two systems using output from the Hadley (Had) and Generalized Fluid Dynamics Laboratory (GFDL) models. Output from the GFDL model run under the B2 emissions scenario was used, while output for the A2, B2, and A1fi emissions scenarios was extracted from the Had model. The results for the Rio Naranjo watershed area are shown in figure 13, while those for the Rio San Jose/Rio Shutaque are shown in figure 14.

Notice that while all GCM/emission scenario combinations predict that temperatures will increase in Guatemala in 2050, the GFDL model suggests that precipitation will increase relative to historical conditions in 2050 while the Had model predicts drier conditions. The mid-century conditions shown

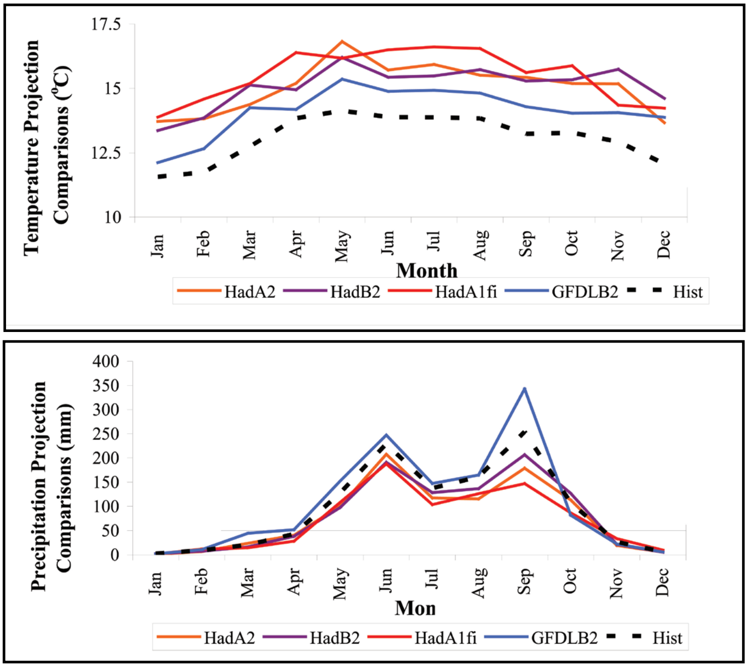


Figure 14: Estimated Mid-Century Changes in Monthly Temperature (top) and Precipitation (bottom) for the Rio San Jose and Rio Shutaque Watershed areas

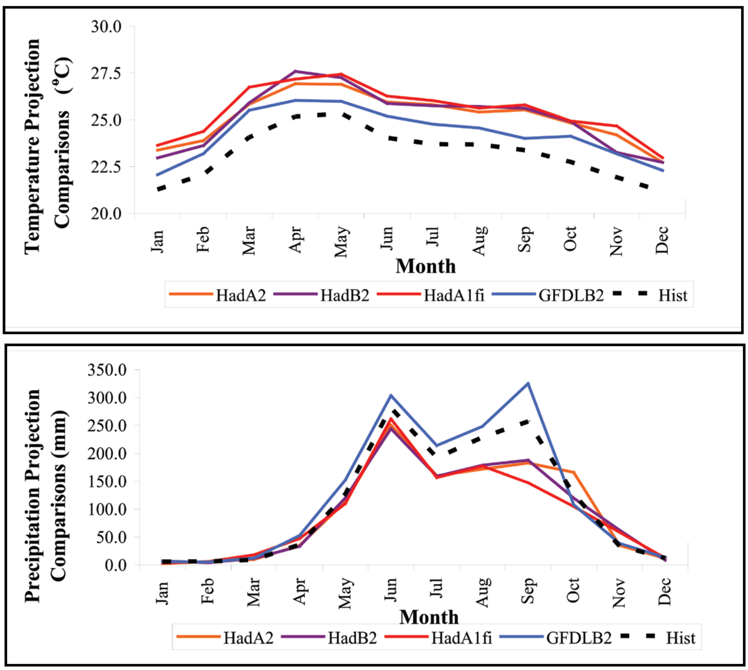


Figure 15: Simulated Mid-Century Streamflow Conditions in the Rio Naranjo below San Marcos under Different Climate Scenarios

in figures 13 and 14 were used to develop a set of factors that were used to challenge observed climatic time series so that they transitioned from currently observed conditions towards those predicted by the GCMs run under different emissions scenarios.

f. Assessing Impacts

Using these the climate time series derived from consideration of the GCM output downscaled in figures 13 and 14 to run the Rio Naranjo and Rio San Jose/Rio Shutaque WEAP applications, it was possible to assess what the impact would be on critical water factors. As an example, the simulated mid-century streamflow conditions under possible future climate conditions in the Rio

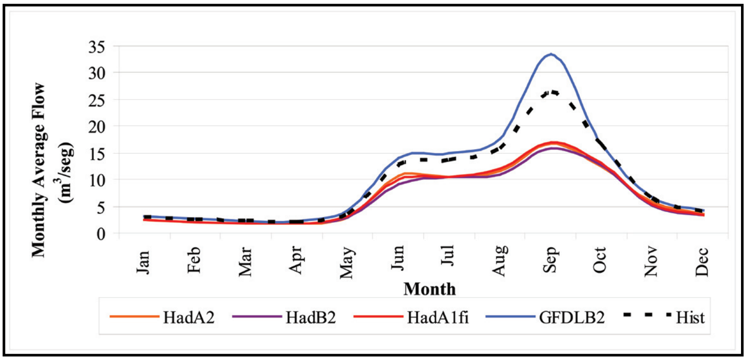


Figure 16: Simulated Mid-Century BOD Conditions in the Rio Naranjo below San Marcos under Different Climate Scenarios

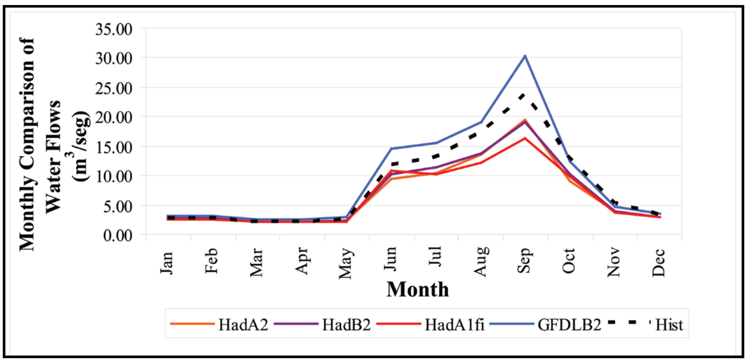


Figure 17: Simulated Mid-Century Streamflow Conditions at the confluence of the Rio San Jose and the Rio Shutaque under Different Climate Scenarios

Naranjo below San Marcos, of interest to stakeholders in a decision making process due to the proposed construction of an urban wastewater treatment plant, is shown in figure 15. The simulated Biological Oxygen Demand (BOD) at the same point for the same time period is shown in figure 16. It should be pointed out that these results were derived from a WEAP application that assumed that the population of the city of San Marcos would grow in the future at a rate which steadily declines from the current 2.4% per annum level to 0.2% per annum in 2050.

These figures provide some compelling potential insights for decision makers developing a wastewater treatment strategy for San Marcos. The first insight is that the worst case scenarios suggest a significant decrease in the flow in the Rio Naranjo relative to current conditions. This has implications in terms of the potential assimilative capacity of the Rio Naranjo as a water receiving body. Alternatively, the most optimistic scenario suggests that flows will increase. However, all scenarios agree that the increased population and the increased temperature will combine to create significantly higher BOD in the Rio Naranjo in the future relative to current conditions. This impact assessment information is of relevance to stakeholders in this decision making process

Figure 17 provides another example of potentially relevant impact analysis. This is the simulated mid-century streamflow at the mouth of the Rio San Jose/Rio Shutaque system compared with current conditions. Recall that one current decision making processes in Guatemala pertains to whether or not water should be transferred from the Rio Shutaque watershed area to meet high water demand in the Rio San Jose watershed area. This decision certainly relies in part upon an assessment of the total aggregate water supply. It may be useful for decision makers to know that some climate projections suggest that the total yield of these watershed areas will be reduced in the coming decades.

7. Mapping the Analytical Tool for the Points of Engagement

Returning to the main theme of this paper, namely finding appropriate points of engagement with actual policy setting and decision making processes for the introduction of climate change adaptation considerations, some concrete examples derived from the experience of the PNCC team over the course of the NCAP project are appropriate. One conclusion that can be drawn from this experience is that not all policy and decision processes can be informed by climate change considerations. For example, one process encountered during the NCAP process involved creating a real-time water allocation dispute resolution policy in the Rio Naranjo. The focus here is on creating a structure which can be called upon to resolve the conflict related to the current actual availability, or more correctly scarcity, of water. The status of the hydrological regime decades from now under an uncertain climate change future is not particularly relevant in this context.

Even in processes where climate change would seem to be more relevant, such as the setting of water quality standards and the design of a wastewater treatment infrastructure, this inference is not always evident to those involved in the negotiations. The strategy developed by the PNCC team at the awareness raising point of engagement was to attempt to develop what were called storyboards that cast the analytical framework presented in figure 4 in the details of the process in question.

The challenge at the awareness raising point of engagement was that the project team could not significantly move beyond general linkage and information flows, and owing to skepticism on the part of the participants about developing this information, there was little expectation that such a development was possible. The general response of those to whom the storyboards were presented can be summarized as: ‘We have heard of this sort of technical analysis in the past, particularly from experts coming from Ciudad Guatemala or abroad, and have yet to experience a time when it came to fruition. It is better to make our decisions based on our own current and local understanding of our system’. It is likely that this reaction is not unique to the watershed area managers and stakeholders of Guatemala.

As an alternative, the NPCC contemplated the potential benefits of developing a series of educational materials that were less technical in tone. Experience with this approach in Peru was considered exemplary. It was here that the posters shown in figure 18 were developed in an effort to raise the awareness about climate change in specific sectors. These posters suggest that a time is coming when the supply of staple foods, fish and fruit will be reduced because of climate change and ask the question, ‘What will happen then?’

The implicit assumption in these materials is that some analysis has been done to characterize the status of stable food, fish stocks and fruit production under some future climate regime. This is the sort of analysis summarized in a storyboard, analysis which was considered untenable by many of the participants in the policy setting processes. Some work needs to be done to characterize the impacts of climate change before effective educational materials can be developed. Viewed in these terms, it perhaps should not be surprising that the PNCC found relatively little understanding at the awareness raising point of engagement during its interactions with participants in ongoing water management dialogues.

Figure 18: Educational Materials to Raise the Awareness of Climate Change

The next potential point of engagement was the implementation of the impact analysis required to understand the implications of climate change on the water resources of the two target basins, in effect, to implement the analytical framework shown in figure 4. This became the major focus of the NCAP activity in Guatemala and while local water managers and stakeholders did provide some valuable insights into this effort, they adopted somewhat of a “wait and see” position towards the project. In fact most of the effort needed to gather the information required to implement the analytical framework was directed at the custodians of national databases in Ciudad Guatemala. This is unfortunate as it is likely to have resulted in a missed opportunity to build ownership of the analytical process among the participants in the policy dialogues. Recall also that one of the steps in the development of the analytical tool was calibration using historical climate data. This tool could be beneficial to decision makers whether or not they would chose to use it to investigate climate change impacts and adaptations.

In any case, it is at this point in the analytical process that some tension can arise between what can be referred to as the data camp and the modeling camp. The data camp would argue that there simply is not enough information available to implement the analytical framework shown in figure 4, and that in any case potential climate change impacts are still some years off. Better to use available time and resources to improve monitoring and data collection. On the other hand the modeling camp would argue that there is a lot of information available, albeit incomplete and poorly organized. Better to use available time and resources to organize it into imperfect modeling tools so that we can get a preliminary idea of potential climate change impacts and identify gaps in the available data. Figure 4 clearly emerges from the modeling camp.

One risk that must be recognized by the modeling camp is that the assessment of impacts that will emerge from implementation of the analytical framework will be uncertain. Finding ways to describe the sources of that uncertainty and to convey its implications to decision-makers and stakeholders is a critical component of impact assessment. Nonetheless, there are important reasons to engage with participants in policy setting processes during an impact assessment, not the least of which is to identify the impacts relevant to a particular decision. For example, a process targeting the establishment of water quality standards and the development of a wastewater treatment plan of action for the Rio Naranjo will be interested in potential changes in river water quality under climate change at specific places along the river. In fact it was interactions with the stakeholders involved in this process in San Marcos that lead to the definition of the decision factors shown in figures 15 and 16. Again, here the PNCC team was honest enough to recognize that for some decision making processes the impact analysis they would produce would not be informative.

The final point of engagement, namely defining appropriate adaptation strategies, certainly cannot be undertaken without the full participation of actors in a particular decision making process. Failure to develop comfort with the analytical tools and to allow the stakeholders to contribute to the definition and evaluation of appropriate adaptation strategies will condemn the analytical framework to the purely academic arena. Producing results showing that a wastewater treatment plant, sized based on information about historical climatic and hydrological conditions, should be expanded in order to accommodate climate change will likely prove impossible to digest for decision makers who have not been involved in reaching such a conclusion. Here it can be said that the PNCC has worked to promote the WEAP application that they developed with stakeholders in the Rio Naranjo system so that the participants in the water quality negotiations can propose and consider their own adaptation options.

8. Implications for the Use of Models

There is an old adage that states that ‘All models are wrong, some are useful’. This seems relevant to this paper regarding the appropriate point of engagement in water management decision making process for those interested in climate change adaptation. It suggests that the builders of models need to be honest with the users of model about the assumptions that went into model construction and their implications for interpreting model results. By the same token, model builders should not be afraid to share the insights that are gained through the modeling process. In the case of Guatemala one critical insight was that in spite of the belief in some camps that sufficient data was available to implement the analytical framework shown in figure 4, the PNCC was able to assemble and process all of the data needed to build the WEAP applications which calibrated reasonably and which yielded pleasing results when run under a range of future climatic conditions. While by no means perfect, these models are at least based on factual predictions.

This leads to a second insight, how could one, without the use of a model arrive at any point of knowledge regarding potential climate change impacts on something like BOD in the Rio Naranjo below San Marcos. While it is certainly legitimate to question just how the information in figure 16 should be factored into the final decision regarding the proposed wastewater treatment plant at San Marcos, it would seem naïve to ignore the information completely. Much of the current research on climate change adaptation involves refining the exact approach that should be taken to integrate climate change consideration into planning, with major contributions emerging from the actuarial sciences and decision theory. As this approach is refined over time, the effort invested now in using models to develop information like that presented in this paper, and in building the level of understanding of and comfort in the analytical process within which these models fit, will be considered a very strong foundation for future efforts to plan for a future in which the climate stands to be very different than the one experienced today.

9. Recommendations and Conclusions

At the beginning of this paper, a statement was made that while the NCAP work in Guatemala focused on the water sector, an effort would be made to develop a general structure for successful engagement with policy makers and decision leaders on the issue of climate change adaptation. That effort will be made here.

At the awareness raising point of engagement, it seems to be of little value in terms of contributing to a policy setting or decision making processes to draw broad conclusions about the impacts of hypothetical climate change scenarios. Quite honestly the mass media is already filling this role.

Hardly a day goes by without some report on melting glaciers, more intense and frequent fires, shifting ecosystems and the link to climate change appearing in print or over the airwaves. Instead, decision makers need to have information on what these changes mean for the decision at hand. Here is it prudent to say nothing if the implications of the decision are of such a limited time horizon that they cannot possibly be affected by changes that will take decades to fully materialize.

There are decisions, however, where the time frame over which climate change will increase in severity are extremely relevant. These include decisions on investments in infrastructure which will be paid off and operated over a period of decades. Political and legal negotiations that are unlikely to be revisited for decades are another reasonable arena for climate change considerations. Property acquisition to meet a specific objective is another. A very relevant function of the climate change adaptation community is to develop preliminary sensitivity analysis of what are considered climate critical decisions in a particular sector. The goal of these analyses should be to show in a general manner what a difference a choice might make if plausible climate change considerations where realised. This should be the focus at the awareness building point of engagement.
At the level of impact assessment, a general recommendation is that the factors that will be assessed must emerge from an actual decision making process. It is of little benefit to describe how certain factors will change under future climate scenarios if they are of little relevance to the decision at hand. This would be a mandatory point of engagement and would have the added benefit that an effort could be made to improve the understanding of decision makers of the data that will have to be assembled and processed and the models that will need to be developed in order to carry out the assessment. In retrospect it is at this level that storyboards, laying out the general linkage and information flows could be most useful, not at the awareness raising point of engagement. The key is to create a sense of ownership, indeed to create a perceived need for the results of an impact assessment.

The completion of an impact assessment seems another logical point of engagement. Although the climate change adaptation community should to be prepared for two possible responses to the information generated. The first is the reaction that the decision at hand may not be that sensitive to climate change. There are times that this may indeed be the case, even under the worst potential climate change scenarios. If the awareness building point of engagement is properly implemented, climate change insensitive decisions should not have progressed to the level of impact assessment. The second potential reaction to an impact assessment might be uncertainty about how to actually use the information contained in the assessment. Here it would probably be useful to articulate future sensitivities in the language of risk and regret and the cost of climate proofing a particular decision.

This brings us to the final point of engagement, the definition of appropriate adaptation strategies. Adaptation costs money. The decisions are in effect insurance policies against the looming and potentially significant risk of climate change. This should be made clear to decision makers and rhetoric should be developed to help them grapple with the implications of this reality. Here also, the definition of adaptation strategies that will be analyzed should emerge from conversations with decision makers, if for no other reason than because they will have a good idea as to the costs of implementing various options. As experts in their field they will also be in a good position to imagine innovative strategies once they arrive at the point of internalizing the threat posed by climate change.

In conclusion, it seems clear that decision makers, and the analysts with whom they collaborate, are beginning to be able to define the process whereby climate change can be taken into consideration. As such the way forward is not entirely clear yet. This should not be surprising; decision makers have developed planning apparatus over the course of many decades that made the fundamental assumption that the climate experienced in the past will be representative of the climate that will be experienced in the future. Perhaps this report on climate change adaptation planning in the water sector in Guatemala will provide an help towards a new planning paradigm.

Water Resources Management for Climate Adaptation in Mali

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Part One: The Study of Ultimate Users of Water Resources and Dialogue with Communities

The sites selected for this study are Kiban (Koulikoro region), Diouna (Ségou region), and Massabla (Commune of Bougouni, Sikasso region).

1. Objective of the Study

Objectives assigned to the study are specifically aimed at:

- Determining, at the level of the three sites selected, the potential of surface and underground water resources (in quantity and in quality);
- Determining sectors that use the water resources;
- Determining water resources' ultimate users, their current, and future requirements over the next 25 years; and
- Using the WEAP 21 software for modeling the rational use of water resources, with a view to minimizing eventual conflicts.

2. Methodologies Used

In addition to experts' opinions, the methodological approaches that were used in this study are as follows.

Data collection was conducted in three phases:

- Documentary retrievals allowed for the collection of all documents likely to contribute to the document that takes into account all the elements of the terms of reference of the study. This data was collected for each locality.
- Holding of village assembly meetings: the consultants went to the sites to carry out dialogues with the water resource users. To this end, a general assembly meeting was held at each of the three sites in the presence of all social groups of the population, to collect data on potential water resources (underground and surface) and the population's essential needs from these resources.
- Analysis: data collection was followed by its analysis and a comparison of the data in order to select the most reliable data. The documentary analysis was made in three parts: climate data, agro-sylvo-pastoral data and socio-economic data. After documentation analysis, information collected during the general meetings held in villages, was also analyzed.

Starting from a baseline situation (the reference climate scenario) the average of the main climate parameters (temperature, rainfall, wind speed, etc.) over the period 1971 to 2000 were determined. The main elements for characterizing water resources (underground and surface) available in the three sites were determined. Then, an assessment of water requirements for the various socio-economic activities (agriculture, livestock, handicrafts, market-gardening, etc.) was carried out in the three sites. Finally, the comparison of each use of the available and potential water (underground and surface) and demands for meeting the main socio-economic requirements, suggested whether the existing potential supply met all the requirements and if yes, with what limitations.

This same approach was used in the case of a climate change scenario where the main meteorological parameters concerning the three sites stem from a climate change model built for Mali. This analysis allows for determining of this temporal horizon, and the impacts of the climate change scenario on water resources in the three sites.

Finally, the knowledge of the potential impacts of climate change will allow for formulation of the most appropriate adaptation options for each site in the field of water resources.

3. Results Obtained

3.1 Determining the water resource potential

For the purpose of the study and with the help of local populations, a rough estimation of the potential of the three sites for availability of surface water was made by using experts' opinions.

3.1.1 Availability of surface water in the three communes

Table 1: Surface water available through ponds and lowlands

Commune	Nature of water sources	Volume of water (m^3) mobilizable per	Presence of water retention structure
Diouna	A network for 9 contiguous ponds	50,000	No
Kiban	A big pond (river)	23,000	3 dams, the inadequacy of which causes the early drying up of the pond.
Masabla	Lowlands and the Mono river	10,000 30,000	No No

Source: Survey by the team on sites – 2006.

In each of the communes, there is a network of ponds and lowlands. Constraints and limitations related to the use of surface water resources are of three kinds:

- Irregularity of the rainfall and prevailing hydrological conditions (the average rainfall for the last 20 years is lower by 15 to 20% than that of the previous years); which cause a decrease in the flow rate of rivers and the fast drying up of ponds and lowlands.
- Whether rainwater drains away fast or not. An absence of small dams and lowlands management schemes allow for an accumulation of standing water.
- Almost all ponds and lowlands in the three localities are clogged; which made the populations of the three communes propose the deepening of ponds and the construction of micro-dams on the Mono River as priority adaptation options.

3.1.2 Quality of underground water used as a safe drinking water supply

During the village assembly meetings (Figure 1), the populations of the three communes were interviewed in relation to the quality of water and the status of water resources.

Figure 1: Assembly meeting in Diouna

a) The Water Issue

Water quality is considered poor when it is unsafe for human and livestock consumption meaning that it could be a source of diseases.

Table 2: Quality of water used for various uses

Commune	Population's consumption	Agriculture	Market-gardening	Drinking water for animals	Handicrafts
Diouna	Poor	Good	Good	Poor	Good
Kiban	Poor	Good	Good	More or less Good	-
Masabla	Good	Good	Good	Good	-

Source: Survey by the team on sites – 2006.

During their village general assembly meeting, the population of Diouna deemed that their water is of poor quality for human and livestock consumption. However, for agriculture and market-gardening, the quality is acceptable.

In Kiban, only 20 wells out of the 450 traditional wells counted there, do not dry up. The water-pumping devices for these 450 wells are hand-powered. Water from wells is of a poor quality. The drinking water for the population comes from the safe drinking water supply network but in the case of water shortage in the network, the population is compelled to drink water from wells. The quality of the river water is good enough for watering livestock during periods of high waters; that is to say during and at the end of the rainy season. As soon as the water level goes down significantly, water quality becomes poor and there is an increased risk of disease for livestock.

In the locality of Massabla, the river water is of good enough quality for watering livestock during periods of high waters. As soon as the water level goes down significantly, water quality becomes poor. When this happens the population gets their drinking water from the pumping system.

b) Water Requirements Coverage
The water requirements coverage for the three localities can be summarized as follows:

- *Commune of Diouna:* Following the village general assembly meeting, the current status of water requirements coverage was deemed by the population as not satisfactory because it does not reach their requirements.
- *Commune of Kiban:* The population deemed that there are deficits in all sectors of water supply.
- *Commune of Massabla:* The population is supplied with safe drinking water from the pump. Having just one watering point is insufficient and is the source of disputes within the population. The same problem was observed in the other sectors of water use as shown in Table 3. Apart from the pump installed in the borehole, all the other wells in the village dry up from February every year.

3.2 Determining the water use sectors

Water use sectors were grouped into three types: domestic, industrial and agricultural. The water use sectors on the three sites selected for the study were:

- Supplying the population with drinking water;
- Supplying drinking water for livestock;
- Agricultural supply;
- Supplying market-gardens and for the watering of gardens and plantations; and
- Supplying the fisheries.

3.3 Determining current and future water requirements

3.3.1 Estimation of water requirements in the case of the reference scenario

Because of the lack of statistical data, during village assembly meetings it was necessary for the villagers to make estimations with the support of consultants and communal authorities. These estimations are shown in Table 3. Estimations of water requirements for the agriculture sector in 2005 are indicated in Table 4.

Table 3: Water requirements (m^3) for the population and the livestock sector in 2005

Commune	Water requirements (m*3*) by the year 2005			
	Population		Livestock	
	Number	Requirements (m^3/day)	Number	Requirements
Diouna	1,051	23	4,780	105
Kiban	8,744	192	11,732	258
Masabla	1,595	35	338	7

Source: Survey by the team on sites – 2006

Table 4: Water requirements (m^3) for the agriculture sector in 2005.

Commune	Rice (m^3/year)	Market-gardening (m^3/year)	Cotton (m^3/year)	Ground-nut (m^3/year)	Maize (m^3/year)	Millet/ Sorghum (m^3/year)
Diouna	0	60,000	0	1,394,250	2,666,800	7,735,000
Kiban	624,000	120,000	0	14,300,000	1,033,385	44,330,000
Masabla	208,000	36,000	680,000	107,250	226,678	728,000

Source: Survey by the team on sites – 2006

3.3.2. Estimation of future water requirements in the reference scenario case

From these elements, the population's needs for meeting the main socio-economic requirements were estimated and shown in Tables 5 and 6 below:

Table 5: The population's water requirements (m^3) for the livestock sector by 2025

Commune	Population		Livestock	
	Number	Requirements (m^3/day)	Number	Requirements
Diouna	1,400	75	11,245	337
Kiban	22,495	497	27,599	828
Masabla	3,407	31	795	24

Source: Survey by the team on sites – 2006

Table 6: Water requirements (m^3) for the agriculture sector by the year 2025

Commune	Rice (m^3/year)	Market-gardening (m^3/year)	Cotton (m^3/year)	Ground-nut (m^3/year)	Maize (m^3/year)	Millet/ Sorghum (m^3/year)
Diouna	0	108,367	0	2,518,171	4,816,537	13,970,270
Kiban	1,127,103	216,733	0	25,827,391	1,866,408	80,064,911
Masabla	375,671	65,020	1,228,156	193,705	409,406	1,314,849

Source: Survey by the team on sites – 2006

3.4 Use of Water Evaluation and Planning (WEAP) software for modeling water resource use

The main objective of using the WEAP is to see whether water availability in each of the sites allows for covering the main socio-economic requirements of the populations of these communes in two different climate situations.

Firstly, the model is operated by introducing meteorological parameters from 1971 to 2000 which correspond to the reference scenario, also referred to as the baseline scenario. The assumption is that this climate scenario will be repeated in the future, from the year 2005 until the year 2025, but that there will be an increase in requirements, associated with population growth.

Secondly, meteorological parameters are taken from the climate scenario that was elaborated for Mali. The reference year retained is 2005 and the upper time limit of the simulation is 2025. The projections of meteorological parameters and requirements evolve regularly for the period between 2005 and 2025 (population, livestock, orchards, kitchen-gardens, etc.). In general, this climate scenario implies that the normal precipitation is going to decrease by about 0.5%/year whereas the normal temperature is going to increase by about 0.2%/year.

In case water requirements are not met, scenarios for adaptation to the harmful effects of climate change will be worked out.

Finally, the results of these various scenarios (reference and climate) and eventually those of the adaptation scenario can be compared by the WEAP which makes it possible to know whether there is stagnation, acceleration or mitigation of the unmet water requirements.

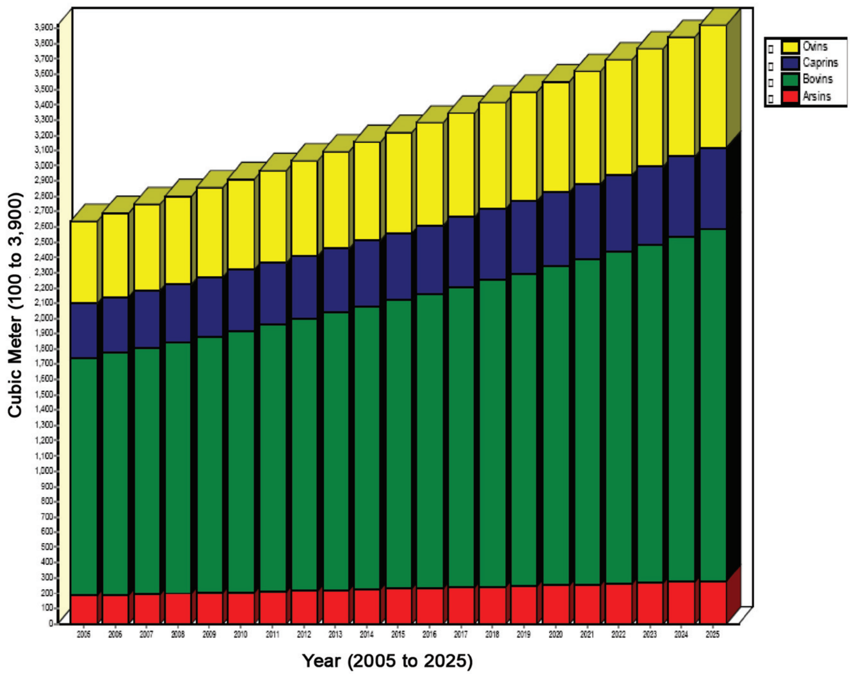

Figure 1: WEAP profile of water requirements for livestock from 2005 to 2025 in Massabla

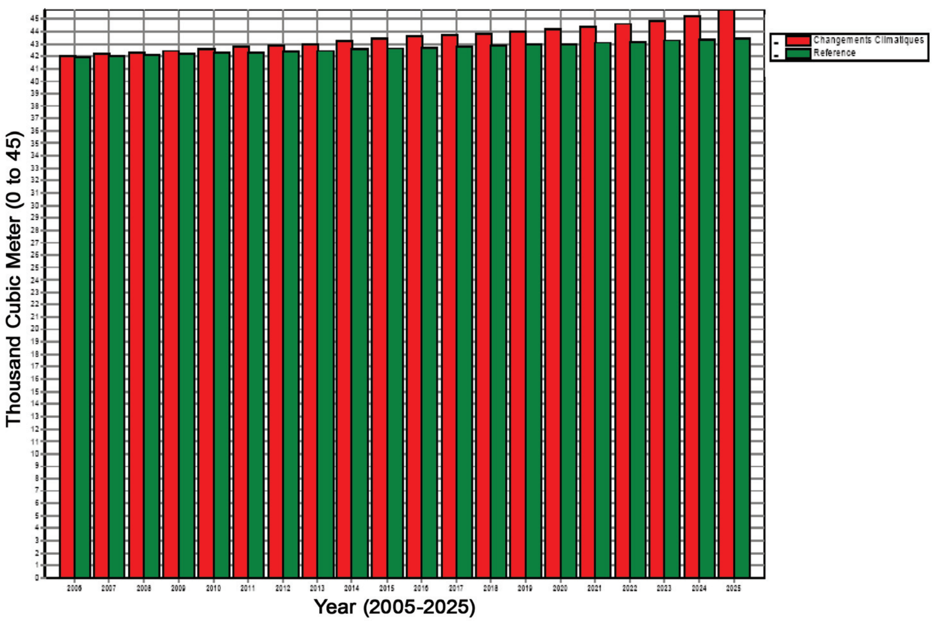

Figure 2: Unmet requirements in Massabla in the case of the reference and climate scenarios (*Red:* Climate change, *Green:* Reference)

At the level of the three communes, we have the same types of water requirements and the same water availability (underground and surface water).

For the commune of Massabla, we added an additional water requirement: irrigation. In fact, the Mono River crosses most of Massabla. In this case the priority adaptation option that was formulated by the population is achieved, as use of the Mono River would offer the possibility of irrigating 15ha of rice according to DNH estimations. By integrating this possibility and by assuming that a micro-dam will be constructed on the Mono River in 2005, we changed the rice growing area from 1ha in 2005 to 15ha in 2025. The WEAP model operated with data from the two climate scenarios.

As with the commune of Massabla, using the WEAP model for Kiban and Diouna reveals a deficit when one takes into account issues such as the drying up of ponds three months after the rains stop and the drying up of wells around March and April.

Generally, water resources available in these three sites are not sufficient for meeting the water requirements of these populations.

4. Recommendations

Following this study, it was recommended that low cost structural changes were carried out, such as:

- The deepening of the ponds in Kiban and Diouna and the construction of water retention dams;
- The construction of a micro-dam on the Mono River in Massabla; and
- The realization of new drinking water supply systems and the repair or replacement of faulty equipment.

To protect pond beds from silting up with sand, evaporation, and for timber production, ponds are surrounded with a 50ha forest belt of trees that doesn't need too much water and a 100ha controlled area that will strengthen the carbon sink and prevent land degradation around the ponds.

The implementation of these adaptation measures will cost 350 million Francs for constructing the micro-dam and 150 million Francs for the deepening of each pond and its maintenance.

In summary it is recommended that:

- Community elected leaders need to adopt such environmental projects into their local development plans and get in touch with the ANICT for their funding. This agency offers up to 95% of the costs of funding environmental projects;
- Access to safe drinking water and to sanitation systems is improved through the promotion of photovoltaic solar energy;
- Agricultural water resources are used sustainably through small-scale irrigation development;
- Water resource availability is increased through constructing water mobilization structures; and
- Appropriate water management technology is needed in order to keep costs down.

Part Two: The Identification and Selection of Appropriate Water Resource Management Technologies

5. Purpose

Objectives assigned to this study, carried out in the localities of Massabla, Diouna and Kiban, are specifically aimed at:

- Making an inventory of the technology used in the field of the adaptation of water resources to climate change;
- Identifying and selecting the most appropriate technology;
- Proposing better technology if necessary; and
- Proposing a technology transfer methodology.

6. Methodology

The methodological approach can be summarized as follows:

6.1 Bibliographical study

- Documenting the climate scenario envisaged for Mali and predicting the impacts on water resources in the study zone;
- Collecting of water resource management both in Mali and worldwide; and
- Gathering relevant socio-economic data as well as the costs of existing technology.

6.2 Site visits and surveys

Site visits were carried out in order to obtain a better knowledge of the physical and human environments in the study zones. Data collection took the form of interviews or discussions in groups or general assembly meetings with the population, local authorities and development organizations operating in each zone.

6.3 Water requirements analysis, assessment of their potential, and resource management simulation

Water requirements were assessed from the data collected in the field and their management according to the expected climate changes was the subject of simulation with the WEAP.

6.4 Analysis of technology offers, definition of selection criteria and proposal for appropriate technology for the study zones

By taking account of the economic conditions and the possibility of ownership of this technology by the communities, it was possible to propose new technology suitable for the environment as well as a methodology for the transfer of the technology.

7. Results Obtained

Gradually the effects of the various adaptation options were simulated. Adaptation options to overcome the water deficit in Massabla were as follows:

- The construction of 40 modern boreholes; and
- A doubling of their capacity from 8 m^3/day to16 m^3/day.

7.1 Impact of climate change scenarios on water resources

Results of climate change scenarios

In the three localities, an average air temperature increase of between 0.7°C and 1.5°C is predicted by the year 2025. It is also predicted that the rainfall will drop by between 3% and 10%. The maximum deficit is predicted at between 19 and 23mm in the dry season.

Sensitivity of water resources to climate change

a) Locality of Diouna:

Ponds (Figure 4) which are the main source of surface water (Table 7) in the commune will be the most sensitive to climate change. The pond in Diouna plays a crucial role in the development projects of the commune such as off-season cropping, fish-breeding, supplying drinking water to livestock, etc.

Figure 4: Pond site in Diouna

Table 7: Water resource sensitivity to climate change in Diouna

	Increase in temperatures	Decrease in rainfall	Indicator
Ponds	4	5	9
Traditional wells	3	4	7
Modern wells	2	3	5
Bore holes	1	2	3
Impact indicator	10	14	-

The most exposed underground water resources are wells, with boreholes being the least sensitive to climate change.

(b) Locality of Kiban:
Safe drinking water mainly comes from wells and boreholes. The other sources for basic activities such as off-season cropping, supplying drinking water to livestock, fish-breeding or household work, are rivers and ponds. These sources of surface water to the commune are the most sensitive to climate change risks. The climate change forecast will be very important in the commune of Kiban, given the primary role played by the Dehara, Lambakoré, Lambaguilé and Souralanibine Ponds in the main livelihood activities of livestock breeding, market-gardening and fish-breeding.

The most exposed sources of underground water are wide-diameter wells, of which there are many in the commune. Boreholes which are less sensitive to climate change are of more of a benefit to the commune.

(c) Locality of Massabla:
This zone has the greatest diversity of water resources of all the communes studied although the impact indicators are highest. There are many lowlands which are highly vulnerable to climate change. Next are the rivers, which are at a fairly high risk. The other water sources in the zone present vulnerability ranging from average to low depending on the extent of the climate change.

In conclusion, on all three sites an increase in temperature and a decrease in rainfall have been observed. The consequences of these changes are as follows:

- A decrease in farm yields;
- The appearance of rangelands;
- The annual drying up of water courses and other areas of surface water (the Mono River is the main surface water resource and is drying up);
- The drying up of traditional wells;
- Yields of rain-fed crops becoming increasingly low;
- More intense heat;
- Difficulties in finding firewood; and
- An increase in the frequency of strong winds.

7.2 Identification of technology used in the study zone

On the various sites, underground water is collected through boreholes, and traditional or modern wells.

Modern wells and boreholes are generally meant for supplying safe drinking water to the population. However, in Massabla, the only existing borehole is used for all purposes during the period of the year when water courses and even the many traditional wells have dried up. The technology, techniques, practices and even the procedures encountered on the sites or related to the establishment and exploitation of infrastructures are described below.

Very little technology was developed to aid with the collection of surface water on the various sites of the study outside Kiban where two micro-dams were constructed on the Lambaguilé, Lambakoré, Dehara and Souralanibine lowlands.

For the better management of water, for the benefit of natural plants, dry-farming, supplying water-beds, and soil erosion control, the following practices are measures for adapting water resources to climate changes:

- Draught farming with ridges that are perpendicular to the highest slope of the land;
- The use of organic manure and crop varieties selected according to their resistance to drought, their place in the farming cycle and the nature of the soil;
- Agro-forestry practiced in the Diouna zone; and
- The localized use of chemical and organic fertilizers in Diouna.

7.3 Levying and distribution technologies

Underground water

Regional boreholes are equipped with man-powered pumps with the following trade marks:

- *Vergnet* in Massabla in a poor operating condition;
- *India Mali* in Kiban in an average operating condition; and
- *India Insala* in Diouna in a poor operating condition.

In Kiban, a drinking water supply is achieved through a borehole equipped with a solar pump.

With buckets made out of old rubber inner-tubes, people draw water from wells for market-gardening, supplying livestock with water and even for household purposes, including human consumption. Animal-powered water-raising systems are also practiced in pastoral areas in the communes of Diouna and Kiban.

Surface water

There are no surface water pumping systems on the various sites, apart from water levied by using buckets, wash-basins, and casks for purposes such as watering gardens, or for use in households or for handicrafts requirements.

7.4 Technology used for adapting water resources to climate change

The technology identified on the sites is generally conventional. However, the use of this technology, in particular in rural areas of Mali, caused some difficulties ranging from high costs to the problems of maintaining the pumps. To collect underground water, boreholes, wells and cistern tanks were thought to be the best choice.

To collect surface water resources, a large range of technology is available. The ones that are deemed the most appropriate with regard to adaptation to climate change and in the socio-economic, cultural, and environmental context of our study zones in particular, and in Mali in general are outlined below.

7.5 Proposals for the most appropriate new technologies on the sites of the study zone.

7.5.1 Technological proposals for drinking water supply

In addition to proposals by the Malian administration, this project makes new proposals with a view to supplementing and/or strengthening these choices or making them more accessible to users in terms of cost investment for ownership and sustainability:

- Introduction and research on adaptation of low-cost drilling technology (manual or mechanical);
- Introduction and research on adaptation of low cost water raising systems mainly:
  - » Nicaraguan type rope-pump (man-, animal- or wind-powered or with high output moto-pump); or
  - » PVC pump (Flexi MAS Nicaragua type).
- With the prospect of climate change in line with the proposed climate scenario for Mali, a special emphasis should be placed on the introduction, research on adaptation, and dissemination of man-powered pumps for deep and very deep boreholes mainly:
  - * *India Mark II* (80m to 90m),
  - * *Busch Pump Zimbabwe* (80m to 90m),
  - * *Afridev with Bottom* (80m to 90m).

7.5.2 Agriculture and irrigation
Three main sources of water are available for irrigation in Mali: perennial surface water; nonperennial surface water; and shallow underground water. In our study sites, efforts were made to mobilize the only sources of water available for irrigation i.e. non-perennial surface water and/or shallow underground water (down to 10m for cereal crops and 20m for market-garden crops).
For that purpose, it was suggested,

In a first stage:

- The introduction and use of manual drills jointly with shallow water pedal pumps (4m to 7m) of improved Bangladesh types (ANIP), and with low irrigation cost and low water pumps (Californian Network, Pepsi Drip, Nica Drip, Easy Drip etc.) in Kiban and Massabla;
- Further study of water resources and water-raising devices suitable for irrigation in the physical, socio-economic and cultural environment in Diouna where water beds are at an average depth of 32m and surface flows are non-existent is necessary.

Technological proposals to be tested for their socio-economic viability would be:

- Natural ponds to be deepened or artificial ponds to be built for irrigation and other practices such as fish-breeding, supplying livestock with water, feeding waterbeds etc;
- Drilling technology (manual or mechanical) together with low cost water-raising systems (Nicaraguan type rope-pump with appropriate traction systems, PVC pump etc.).

Technology would also be introduced and/or intensified to allow for optimizing water availability for dry-farming and for feeding waterbeds, previously identified on the study sites or identified from relevant experiences worldwide (lowlands and/or watershed area management schemes, water and soil conservation management schemes, organic manure, farming techniques and technical itineraries, variety selection etc.).

In a second stage:

- The population would need to be taught to use the technology outlined above in order to ensure its sustainability. The socio-economic feasibility of each technology or technology system should be proved so that it can be used sustainably.

7.5.3 Livestock
For livestock, water supply needs to be ensured. In Kiban and Massabla this would be from ponds and small dams. In Diouna, the deepening of ponds is the only water harnessing technology possible, provided that the socio-economic feasibility is proven. That could be done jointly with water and soil conservation technologies to ensure their sustainability. However, the overgrazing and overexploitation of underground water that can be harmful to the environment needs to be avoided.

Therefore the following technology is recommended:

- Deep boreholes with low cost technology;
- Man-powered pumps for deep and very deep boreholes; and
- Nicaraguan type-rope pumps depending on the environment.

7.6 A proposed methodology for technology transfer

The proposed methodology will be based on the approach referred to as the “product and/or market creation approach”. It is worth mentioning that this approach has already proved effective in Asia, Latin America and even in some African countries in the framework of pedal-pumps for small scale irrigation.

The 5 key factors for the establishment of viable and perennial distribution chains are:

- An adequate offer, characterized by (i) the function (the product fulfils the functions for which it was designed); (ii) the price (acceptable for the consumer); (iii) the place (the product is available in sufficient quantity in the required places); (iv) the quality (the product is of a good enough quality); and (v) the promotion, and information available to the consumers.
- Effective incentives for entrepreneurs, the primary motivation being undoubtedly profit, but social motivations can be also important (such as increasing the production of poor farmers).
- An effective information flow between the stakeholders of the chain because information sharing can increase the profit and performances, and reduce individual risks.
- An effective management of the chain: mainly constructing relationships between partners by creating opportunities for meetings by giving partners an overview of the chain and of the product; and by creating an enabling environment that allows for collaboration by the partners.
- An enabling environment: mainly a stable macro-economic situation; an open system of participation of the private sector; access to credit by the formal sector or the unorganized sector. The impact of legislation and tax on small- and medium-sized enterprises and well developed transport and transmission networks. Furthermore, the small private sector takes advantage of the existence of enterprise development services which provide knowledge and training required for assisting small- and medium-sized enterprises in developing. Therefore, it is essentially through these key factors that external agencies can contribute to developing reliable and perennial distribution chains.

This dissemination methodology is based on commercial manufacturing of the technology, without subsidies.

In the first stage, "practical research" is carried out in the field in a way to design technology meeting the following criteria:

- Technically effective;
- Financially affordable by target-clients;
- Economically profitable (rapid return on investment, technical sustainability of the product); and
- Locally manufacturable, as close as possible to clients (ultimate users).

In a second stage, the product is marketed in compliance with rules that will guarantee the sustainability of the product involved:

- The product is primarily meant for a clientele of small private entrepreneurs earning their living from their work, and investing themselves in the product;
- The product is made by local manufacturers taking advantage of the manufacturing and selling of their products;
- Product awareness is ensured by publicizing the name and the use of the new product, and by establishing a commercial relationship between the manufacturer and the client who is also a producer practicing irrigation;
- A "quality control system" is put in place both at the manufacturing and the use levels to make the product known and advertise the image of the product. This "quality control" is necessary to reach a "point of non-return", a time when the image of the product is established; and
- A step-by-step approach is necessary, to prevent a lack of information on its maintenance or on its conditions of use, for example which would lead to bad publicity.

This approach guarantees the sustainability of the manufacturing, the selling and the use of the technology involved. Nonetheless, there exist risks, such as:

- The subsidy to technology, by some structures, can destabilize the approach based on the purchaser's logic of entrepreneurship; and
- The lack of after-sale counseling service close to users.

8. Recommendations Made

An analysis of water resource availability, its evolution, and the demand from all sectors, confirmed the existence of a supply higher than demand. Nonetheless, deficits essentially related to mobilization, water-raising and management were observed on all the sites. These deficits, despite the risks of their increase related to climate change, can be reduced, and even made up through the actions below:

- Joint use of surface and underground water. In fact, the static levels of underground water (lower than 20m in Kiban and Massabla) allow for using them for household purposes, for supplying livestock with drinking water etc. whilst surface water can be used for market-gardening;
- A wide dissemination of low cost technologies (harvesting, pumping, distribution);
- A wide distribution of water and soil conservation technologies (ridge farming, organic manure, agro-forestry);
- The use of water resources planning, prediction and management tools such as the WEAP; and
- The strengthening of agro-meteorological assistance to the rural world, considered today a fundamental element of the strategy for adaptation to climate change in Mali, should in the long run contribute to a better utilization of water resources.

9. Conclusion

The identification and selection of appropriate water resource management technology raises the issue of adaptation (at the technical and financial level) to this technology hence the need for the study on the elaboration of strategies for adaptation to climate change.

Climate Change and Sustainable Livelihood of Rural People in Mongolia

B. Bayasgalan, R. Mijiddorj, P. Gomboluudev, D. Oyunbaatar, M. Bayasgalan, A. Tas, T. Narantuya and L. Molomjamts

1. Introduction

Mongolia is a vast, land-locked country bordering China and Russia. The average altitude is 1,580m above sea level. The country stretches from the Gobi desert in the south to the forest and forest steppes in the north and from the Altai Mountains in the west to the steppes and desert steppes in the centre and east. Mongolia has a harsh continental climate with four distinctive seasons, high annual and diurnal temperature fluctuations, and low rainfall. Because of the country's high altitude, it is generally colder than in other countries on the same latitude. Frequently, the country is hit by so-called *dzud* events, a succession of a very dry summer, an extremely cold autumn and a harsh winter which deprives livestock of grazing, often leading to high livestock mortality rates.

Many people in Mongolia depend on keeping livestock for their livelihoods (see box 1). Estimates indicate that almost four out of ten people in Mongolia hold livestock and in rural areas this figure can be as high as seven out of ten. A large part of the rural population has maintained the traditional lifestyle of moving around with their herds of cattle, goats, sheep, camels and horses.

The high dependency on keeping livestock makes the country and especially the poor rural people highly vulnerable to climate-related hazards. This was shown again in the period 1999 to 2002 when three consecutive *dzud* years killed nearly 30% of the livestock and many rural households were struggling to survive. Recurring drought events have also led to reduced pasture growth and limited water availability further aggravating the poor living conditions of rural households.

Realizing the sensitivity of the livestock sector to climate-related hazards, many people have started to express their concerns about the potential negative effects of climate change on the already vulnerable rural population and in recent years various studies have been undertaken to further investigate the issue.

A study carried out in the context of the AIACC project, for instance, has concluded that over the last 60 years the annual mean air temperature in Mongolia has increased by 1.66ºC. The warming has been most pronounced in winter with an increase of 3.61ºC. The spring and autumn temperatures have increased by 1.4 to 1.5ºC. No clear trend has been detected in summer temperatures. The study did not observe a significant change in mean annual precipitation during the same period. However, it was noted that changes in annual precipitation have a highly localized character and some areas in the country do show a significant increase whereas others show a decrease.

In terms of future climate projections, the results from a selected set of Global Circulation Models show a 3 to 10ºC increase in mean monthly temperature and a small increase in precipitation for the periods 2000 to 2040 and 2040 to 2070. All of the models predict that winter warming would be more pronounced than summer warming, especially after 2040.

According to various scientists, these changes in climate are having and will have a significant impact on natural resources such as water resources, natural rangeland, land use and snow cover.

In the next 40 to 50 years, many *soums* (sub-provinces) in the territory of the Bayan-Ulgii and Khovd provinces (in the western region of Mongolia) will increasingly be affected by desertification, because the amount of precipitation will decrease and average temperature will increase. Also, because of decreased permafrost, perpetual snows, glaciers, lakes, streams and rivers that have their origin in the Khangai Mountain range, will lose their headwater and will eventually dry up completely. They will only have seasonal and temporary flow dependent on precipitation levels. Furthermore, the decrease in permafrost in combination with changing rainfall patterns, will very likely result in an increase in the number of forest fires. Taken together, most of the studies conclude that climate change will negatively impact the natural resource base in Mongolia and will consequently further aggravate the precarious conditions in which rural communities are living[1].

In response to these and other observations, the government of Mongolia has started to formulate legislation and policy measures to prepare itself for the possible consequences of climate change. In 1993, the government ratified the United Nations Framework Convention on Climate Change (UNFCC) and in 2001 it approved a National Action Program on Climate Change. In addition, several policy documents have been put in place that are directly or indirectly related to climate change. These include:

- Laws on Nature and Environment; Laws on Meteorology, Hydrology and Environmental Monitoring; Laws on Land; Laws on Arable Farming; Laws on Disaster Prevention; Laws on Pasture;
- A program on sustainable development of Mongolia, 1999;
- A national program on preventing livestock from drought and *dzud* disasters, 2001;
- A food program on food supply, security and nutrition, 2001;
- A program on supporting development of intensive livestock-farming, 2003;
- A state policy on the development of food and agriculture; and
- Relevant annual reports on the natural and environmental review in Mongolia.

The government has also established an inter-disciplinary and inter-sectoral National Climate Committee (NCC), led by the Minister for Nature and the Environment, to coordinate and guide national activities and measures aimed at adapting to climate change. High-level officials such as Deputy Ministers, State Secretaries and Directors of the main departments of all related ministries and agencies are members of the NCC.

2. Objectives and rationale of activities undertaken

Even though much research has already taken place and certain policies measures have been proposed and adopted, it is recognized that a lot still needs to be done in order for Mongolia to be better prepared for the effects of climate change. In this respect, it has been noted that many people in Mongolia still consider climate change as something that will happen in the distant future and will have limited impact on their daily lives. Consequently there still exists a certain reluctance to start addressing the problem with clear and concrete policies and adaptation measures. In addition, the adaptation measures that have been proposed so far are often very general and sometimes even unrealistic with little reference to the actual situation on the ground. Finally, policies and adaptation measures largely exist on paper and are rarely implemented and enforced due to a lack of financial support and institutional capacity.

1 A database has been compiled by the NCAP project team in Mongolia containing information about climate change projects and publications in Mongolia.

Box 1: The agricultural sector in Mongolia

In recent years Mongolia has been experiencing strong and continuous economic growth. Its GDP grew by 5.6% in 2003 and by 10.6% in 2004. Growth in the agricultural sector turned around from -18.2% in 2001 and -12.4% in 2002 to +4.9% in 2003 and +19.9% in 2004. According to a World Bank report real GDP growth rate in 2007 was 9.9% and has been primarily driven by agriculture (which contributed 3.4% to economic growth), and services (which contributed 4.3%).

Agricultural sector activities predominantly consist of keeping livestock and animal husbandry. The 2007 annual livestock census reported an increase of 15% of livestock from 34.8 to 40.3 million livestock, with the number of goats, sheep and cattle increasing by 18, 15 and 14% respectively. All together, the livestock sector employs 364,000 people or almost 40% of Mongolia's working population.

Even though Mongolia has made notable progress in achieving macroeconomic stability and economic growth since its transition to democracy and shift to a market-based economy, it has also been noted that the social and environmental costs of this transition have been high. This is particularly so in the livestock sector, which has suffered from a decaying rural infrastructure because water wells, pasture irrigation systems and rural transport have not been maintained and have fallen into disrepair. Also the opening up of the Mongolian market has seen a shift from sheep keeping to goat keeping among herders who are trying to respond to the growing international demand for cashmere wool. Goats, however, are much more harmful to the environment than sheep because they disturb the pasture's regenerative capacities by feeding on roots and flowers. Consequently, the shift to goat keeping is putting increasing pressure on the pasturelands in Mongolia, threatening to accelerate pasture degradation and processes of desertification.

The NCAP project in Mongolia, which started in 2005 and ended in 2008, has tried to address some of these issues and has focused its activities on the following areas:

Firstly, the project has taken the support of the NCAP as an opportunity to further the understanding of baseline vulnerabilities in Mongolia. Rather than replicating past efforts, the project team has sought to further build on the existing knowledge and has carried out some more detailed studies in the field of climate science, pasture monitoring, water management and food security with the purpose of developing and formulating more detailed adaptation measures for herding communities in Mongolia.

Secondly, considerable efforts were made to increase public awareness of climate change in Mongolia through the publication of short articles in various newspapers and magazines and the broadcasting of television programs on climate change.

Finally, the project team has collaborated with key politicians and policymakers in Mongolia to further build legal and institutional foundations for implementing climate change adaptation policies in Mongolia and has developed a set of specific and feasible adaptation measures for rural herding communities in Mongolia.

In what follows, an overview is given of some of the key results of the project. Each chapter starts with a summary of the main results of the study reports. Next a summary is given of the activities that have taken place in relation to institution building and the formulation of adaptation measures. The chapter ends with some recommendations and lessons learned.

3. Key results and findings from the studies

In the context of the NCAP project, four interrelated studies were carried out to further develop the understanding of climate change vulnerabilities in Mongolia, with a special focus on rural herding communities. The studies cover different areas related to the livelihood activities of rural communities including exposure to (extreme) climate events, pasture resources, water resources, and food security. The results from the studies have served as a basis for discussing and formulating more specific adaptation measures which are presented in section 5.

3.1 Climate change exposure and extreme events

The study on climate change exposure and extreme events further builds on existing climate science work in Mongolia in three respects. Firstly, whereas previous studies have mainly focused on climate averages, this study has dealt with extreme climate events such as prolonged droughts and harsh winters (*dzud*). Secondly, the study provides an update on the historic trend analysis up to the year 2007. Finally, the PRECIS Regional Climate Model was used to downscale GCM data for key climate parameters and identify vulnerability hotspots in Mongolia.

Trend analysis

According to a linear trend estimation of temperature changes over the period from 1940 to 2007 annual *temperature* has increased by 2.1ºC (figure 1). Most of the increase is taking place in winter (3.6ºC). Spring and autumn temperatures have increased by 1.8 and 1.9ºC respectively and summer temperature by 1.1ºC. Interestingly, the observed increase in annual temperature is higher than the one detected in a previous study which used data from 1940 to 2001 and showed an increase of 1.66ºC in mean annual temperature. This indicates that the years since 2001 are further adding to the warming trend. Also, whereas the previous study did not show a significant increase of summer temperature, the current study reveals a summer warming trend of 1.1ºC.

Annual precipitation has not significantly changed, but it has decreased by 7% in terms of the country's spatial average (figure 2). The direction and magnitude of change differs from place to place and a small increase in precipitation is detected in the east, southeast and the Altai Mountain region whereas the southern part of the Khangai Mountains and the central region of Mongolia show a decrease. These observations are in line with the results from the previous study. It is also noted that convective precipitation is becoming more dominant, particularly in the transition zone between semi-desert and desert areas.

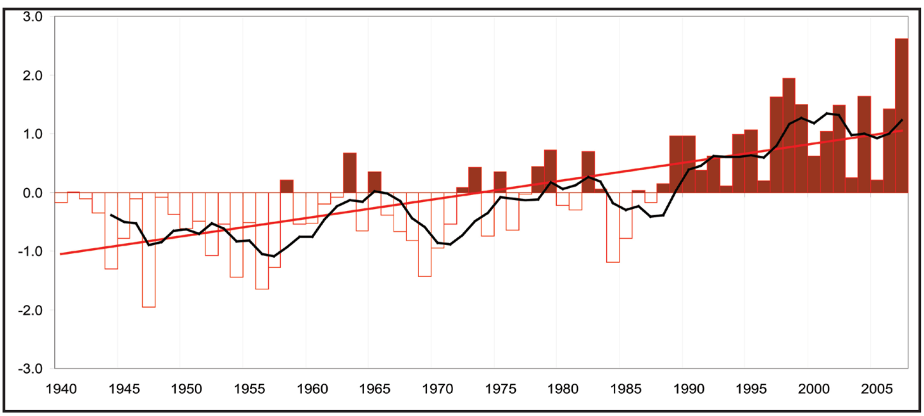

Figure 1: Annual mean temperature anomaly time series over Mongolia, ºC

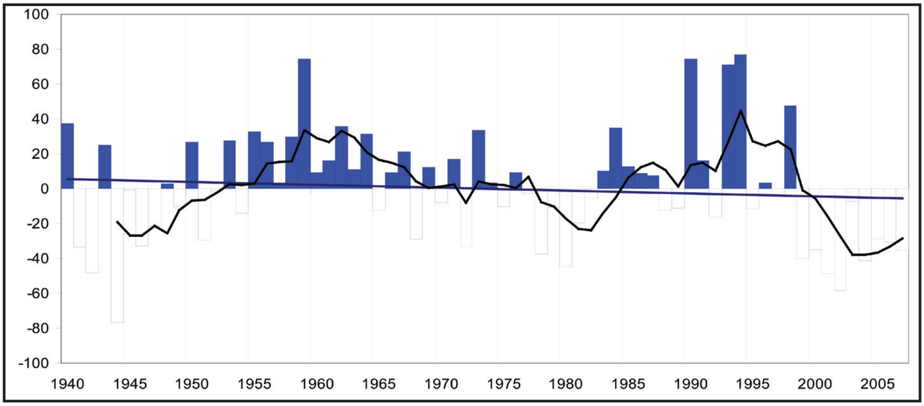

Figure 2: Annual total precipitation anomaly time series over Mongolia, mm

In order to understand changes in extreme events, the study defined a set of *climate extreme indices* as recommended by the CCl/CLIVAR Expert Team for Climate Change Detection Monitoring and Indices (ETCCDMI). An overview of the trends in climate extreme indices is given in table 1.

Table 1: Extreme indices trends based on results from 24 meteorological stations over Mongolia, 1950 to 2006

Index	Definition	Units	Trends
Max Temp (TX)	Monthly maximum value of daily maximum temp	ºC	2.9
Min Temp (TN)	Monthly minimum value of daily minimum temp	ºC	5.2
Cool nights	Percentage of days when TN<10th percentile	Days	-7.1
Cool days	Percentage of days when TX<10th percentile	Days	8.4
Warm nights	Percentage of days when TN>90th percentile	Days	-12.8
Warm days	Percentage of days when TX>90th percentile	Days	12.1
Diurnal temperature range	Monthly mean difference between TX and TN	ºC	-0.9
Max 1-day precipitation amount	Monthly maximum 1-day precipitation	mm	-0.4
Max 5-day precipitation amount	Monthly maximum consecutive 5-day precipitation	mm	-3.7
Simple daily intensity index	Annual total precipitation divided by the number of wet days (defined as PRCP>=1.0mm) in the year	mm/day	-0.2
Number of heavy precipitation days	Annual count of days when PRCP>=10mm	Days	-0.5
Number of very heavy precipitation days	Annual count of days when PRCP>=20mm	Days	-0.2
Very wet days	Annual total PRCP when RR>95th percentile	mm	-4.2
Annual total wet-day precipitation	Annual total PRCP in wet days (RR>=1mm)	mm	-15.0

Extreme temperature indices show an increase in both daily maximum and minimum temperature. However, the warming trend of the minimum temperature is higher than for the maximum temperature. These observations are also consistent with a decrease of the diurnal temperature range over Mongolia.

Concerning the trend in precipitation, a decreasing trend is observed all over the country except in the southwestern region. A relatively high decrease is observed in the central region of the country. This also corresponds to indices of extreme wet conditions. However, more studies need to be done on the type of precipitation and the percentage of heavy precipitation compared to the total amount, especially in terms of areas where severe land degradation is going on. In short, the trend analysis shows that extreme temperature indices are changing towards warming, and extreme precipitation is showing that dryness is becoming more dominant in the country.

Downscaling climate data using PRECIS

Previous studies on climate change in Mongolia have mainly focused on Global Circulation Model (GCM) outputs for assessing the impacts and vulnerability of ecosystems and socio-economic sectors. However, the resolution of a GCM is typically in the range of 250 to 300km which is often not detailed enough to support decision-making processes at a local level. Moreover, local topography and land cover influences on the regional climate are not adequately represented in GCMs. Therefore, this study has used the PRECIS (Providing Regional Climate for Impacts Studies) Regional Climate Model to downscale global model output to the regional scale (50 to 60km).

Even though it is acknowledged that multi-model approaches are essential for understanding and appreciating uncertainties in individual model results, running a Regional Climate Model is in itself very expensive and needs considerable computer capacity, time and experience. Consequently, in the context of this study it was only possible to run one Regional Climate Model and choices needed to be made on which emission scenario to use (A2) and which GCM would be used to set out the boundary conditions for the model (HadCM3). Therefore it is suggested that the results from this study are read with care and are best interpreted in conjunction with results from similar modeling efforts in the region.

Two model runs were performed: the first one to simulate the historic climate for the period 1961 to 1990 and the second one to project future climate conditions for the period 2071 to 2100 using the A2 emission scenario.

Figure 2 shows the observed mean temperature for the period 1961 to 1990, a PRECIS simulation of mean temperature for the period 1961 to 1990 and a projection of future temperature for the 2071 to 2100 period. As can be seen from this figure, the PRECIS simulation results of the 1961-1990 period give a reasonable presentation of the observed temperature in Mongolia in the same period (figure 3 a, b). This gives some confidence about the model's capability to project the future climate of Mongolia although, as was mentioned before, it will be important to interpret the model results in conjunction with results from other modeling efforts. Figure 3c also shows a general increase in temperature in Mongolia for 2070 to 2100 compared to the 1961 to 1990 baseline.

In terms of *precipitation*, figure 4 shows the observed mean precipitation for the period 1961 to 1990, a PRECIS simulation for the period 1961 to 1990 and a projection of future precipitation for the period 2071 to 2100. Again the simulation of the 1961 to 1990 period gives a reasonable representation of the observed precipitation in Mongolia in the same period.

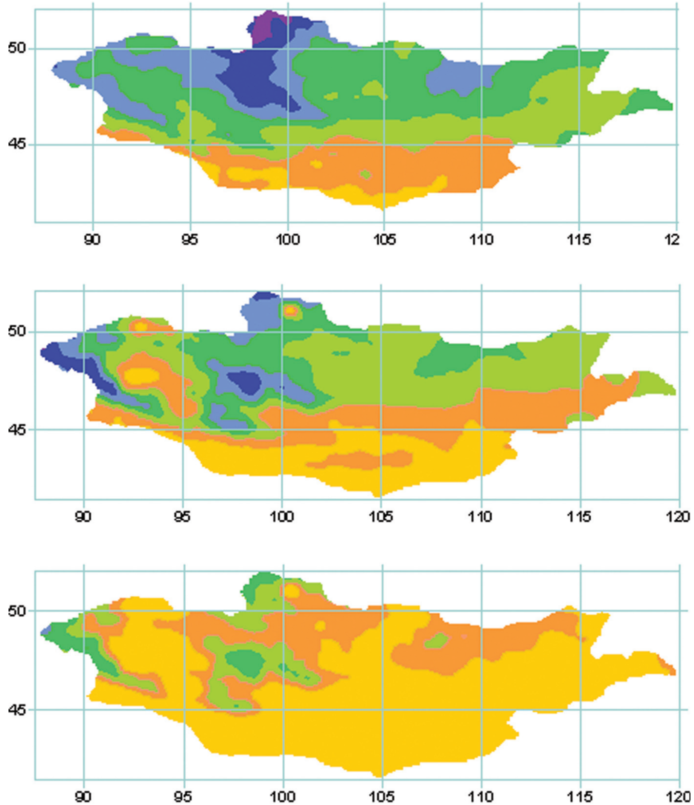

Figure 3: Annual temperature, ºC (from top down) a) Observed climate of 1961 to 1990, b) Simulated climate of 1961 to 1990, c) Projected climate of 2071 to 2100

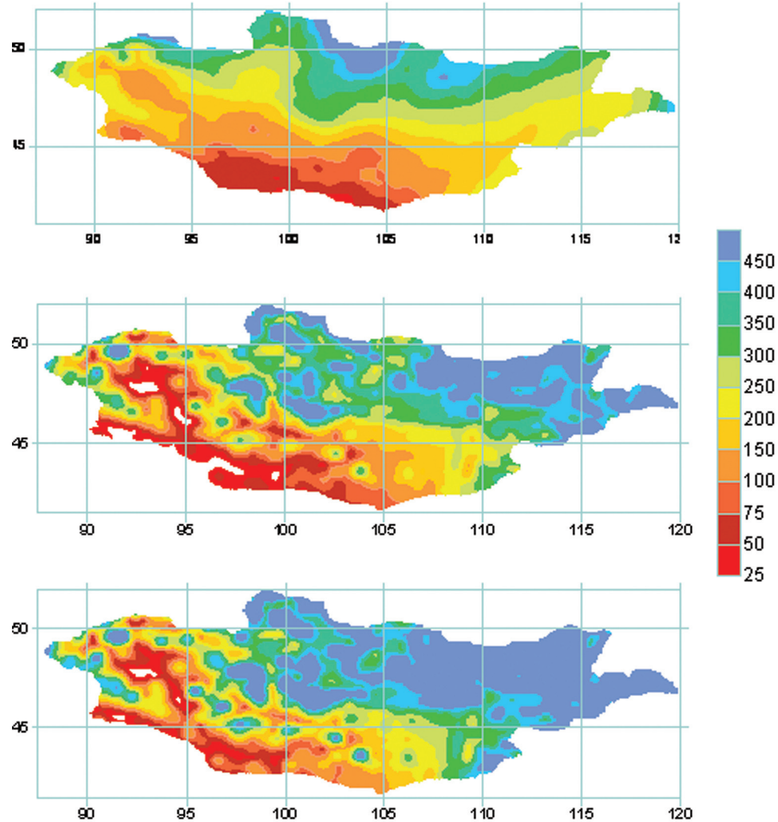

Figure 4: Simulated mean annual precipitation, mm (from top down) a) Observed climate of 1961 to 1990, b) Simulated climate of 1961 to 1990, c) Projected climate of 2071 to 2100

More important than changes in average annual climate, however, are changes in seasonal climates and extreme events. In order to understand changes in seasonal temperature and precipitation, the study has considered differences between the baseline climate and the future climate projections.

Contrary to the trends observed in historical temperature, the PRECIS modeling results for the period 2070 to 2100 show a high temperature increase of 5 to 7˚C during the summer season. Temperature increases for the other seasons are estimated at 4.5 to 5.5˚C in winter, 3.5 to 5˚C in spring and 3.5 to 4.5˚C in autumn. There are also geographical differences with the western and northwestern parts of Mongolia showing the highest increase.

According to the PRECIS model results, summer precipitation will increase by 40 to 60mm in the mountainous region of central Mongolia, and the small areas in the northeast and southeast of the country. The rest of the country shows an increase of 20 to 40mm except for the northwestern part of Mongolia where the model shows a decrease of 20 to 40mm. This is also the area where many glaciers are situated and most rivers are being charged by the permafrost. In autumn, there is a 0 to 20mm increasing in the west and 20 to 40mm in the east of Mongolia. In spring, a 0 to 20mm increase is projected in central and western Mongolia and 20 to 40mm in the east. In winter, there is a 0 to 20mm decrease across the whole territory of the country. If precipitation change is defined and expressed as a percentage of the baseline climate value, then the summer increase is not particularly high, but the winter increase is. The area where precipitation levels are decreasing is the northwestern part of Mongolia.

The above mentioned research results show a significant climate change during the summer season compared to other seasons. If one considers the geographical distribution of the changes, it appears that the western and northwestern parts of Mongolia will be especially affected by global warming.

In terms of future changes in the occurrence of extreme events, the study has diagnostically estimated drought, *dzud* and dryness indices at model grid points using PRECIS model outputs. The frequency is defined for both the periods 1961 to 90 and 2071 to 2100 and expressed as a percentage (e.g. 20% meaning that the event occurs once every five years, and 50% meaning that the event occurs every 2 years). During the 1961 to 1990 period, the occurrence of drought events was relatively equally distributed across the country with a slightly higher frequency in the western and central parts of Mongolia. The future distribution of drought frequencies looks different with a very high incidence of drought events in the northwestern part of the country and a reduced frequency of drought events in the southwestern part.

Finally, based on the PRECIS model results, the study also calculated a dryness index which was defined as the ratio between precipitation and potential evaporation (P/Eo). To summarize, the analysis shows that extreme events like *dzuds* and droughts are expected to become more frequent, especially in the northwest of the country and dry conditions are expected to increase over the whole territory.

Vulnerability of aimags *(provinces) to extreme climate events*

In order to assess the vulnerability of different *aimags* to extreme climate events, the study has developed an index of vulnerability based on both current and future exposures. Because the most important season for herding is summer, the study focused on summer precipitation trends and drought frequency projections in order to assess the relative vulnerabilities of different *aimags*. The results from the assessment are given in table 2. The table shows that 12 out of 18 *aimags* in Mongolia are highly exposed to climate change and climate variability.

Table 2: Extreme climate vulnerability based on the exposure level

Aimag Name	Current	Future	Exposure level
Arkhangai	High	High	High
Bayankhongor	High	Low	High
Bayanulgii	Low	High	High
Bulgan	High	Low	High
Dornod	Weak	Low	Weak
Dorno-govi	Weak	Low	Weak
Dundgovi	High	Low	High
Govi-altai	Low	Low	Low
Khentii	Low	Low	Low
Khovd	Weak	High	High
Khuvsgul	Weak	Weak	Weak
Selenge	High	Low	High
Sukhbaatar	Weak	Low	Weak
Tuv	High	Low	High
Umnugobi	High	Low	High
Uvs	Low	High	High
Uvurkhangai	High	Low	High
Zavkhan	High	High	High

3.2 Pasture resources

Pasturelands constitute one of the key resources for the livestock based economy in Mongolia. According to the 2005 Land Inventory Report, 116 million ha or 73.9% of the total land surface of Mongolia can be considered as pastureland. Being one of the key resources in the Mongolian economy, this study has looked into historic changes in pasture resources and has sought to understand how these changes can be related to changes in climate and other socio-economic developments.

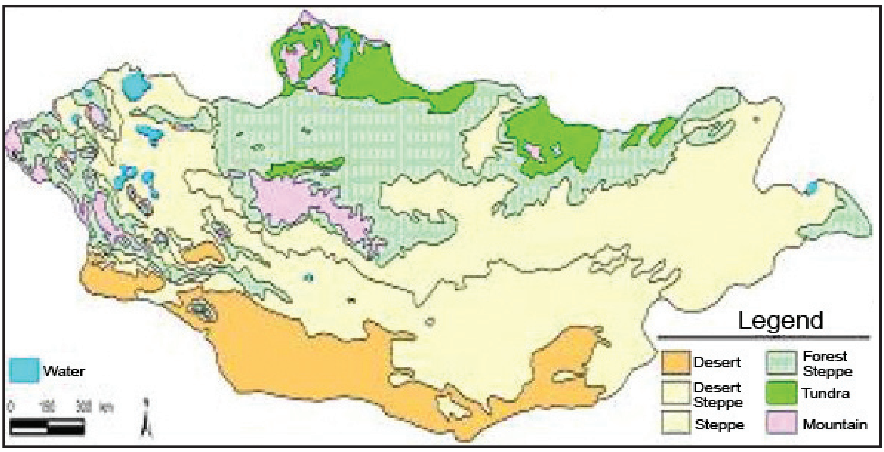

Figure 5: Natural zones of Mongolia

Mongolia is divided into 6 natural zones: tundra; high mountain; forest steppe; typical steppe; desert steppe; and desert (see figure 5). The pasture productivity, dominant species and type, length of growing season and phenology are different for each of these natural zones. The pasture productivity, for instance, ranges between 150 and 1500 kg/ha increasing from the deserts in the south to the forests and forest steppes in the north.

Historic trends in pasture resources

In order to analyze the historic trends in pasture resources, the study has examined the Normalized Difference Vegetation Index (NDVI) using NOAA-AVHRR data. Figure 6 shows the annual NDVI dynamics of the different natural zones of Mongolia. As can be seen from this figure, the NDVI ranges are spatially and temporally different. Tundra, high mountain and steppe zones have a clear seasonal cycle whereas in desert steppe and desert zones such annual dynamics cannot be observed. The figure also shows that the height of the growing season is concentrated during the months of July and August. Consequently, the remainder of the study has focused on these two months.

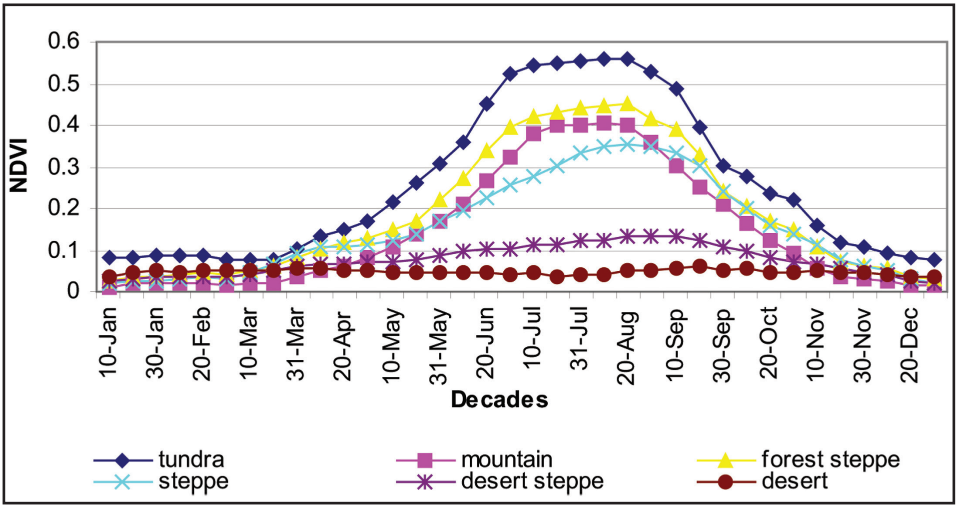

Figure 6: Average NDVI values for the different natural zones in Mongolia

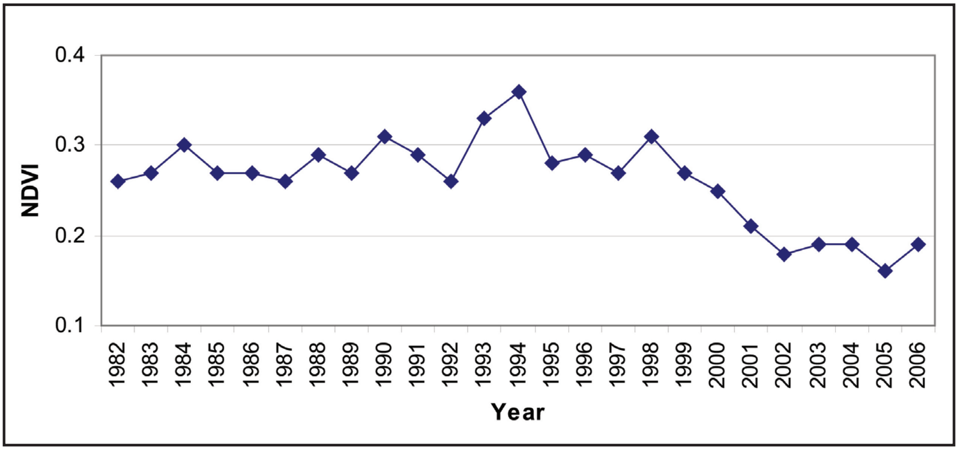

Figure 7: Annual NDVI values averaged across Mongolia

The NDVI changes over the last 24 years for July and August are depicted in figure 7. The NDVI values don't show a significant trend up to 1994. However, from 1994 onwards, a decreasing trend can be observed. This trend can be observed in all natural zones and, in desert steppe and desert zones, the NDVI values are even dropping below the 0.06 threshold of no vegetation (i.e. bare soil).

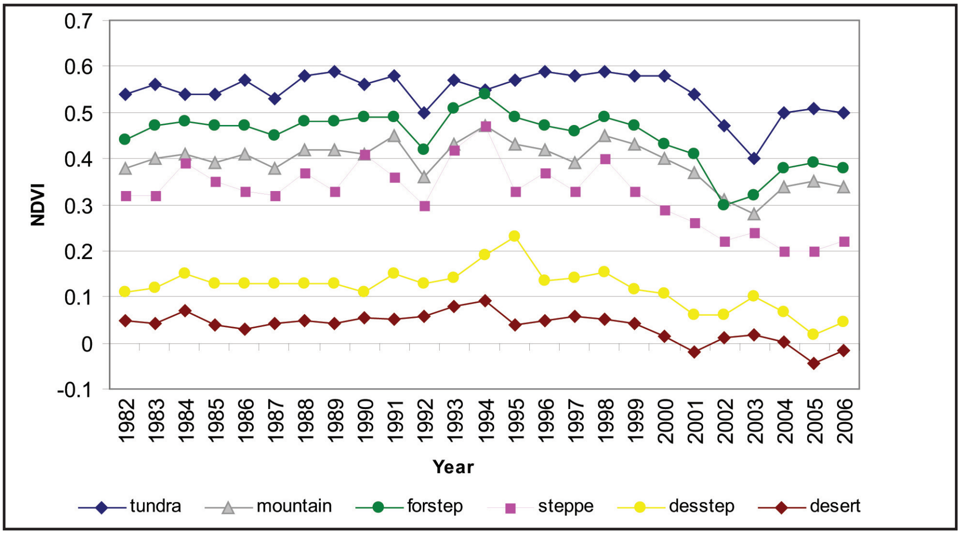

Figure 8: Annual NDVI values averaged across the different natural zones

To further understand trends in pasture resources, the normalized value of NDVI, ZNDVI, was calculated. This also allows comparison of the trends in pasture resources between different areas and regions in the country. ZNDVI is expressed as follows:

$$Z_{NDVI} = \frac{NDVI_k - \overline{NDVI_i}}{\sigma_{k\ NDVI}} \times 100$$

where, NDVI ik and σ ik represent the NDVI value and its standard deviation at point i, of year k[2]. The slope of Z NDVI values for July and August were negative in all sums (figure 9). The lowest values were detected in the *aimags* of Uvs, Arkhangai, Bulgan, Khuvsgul, Tuv, Selenge, Dornod and Omnogobi. This clearly indicates that serious pasture degradation is taking place in many parts of the country.

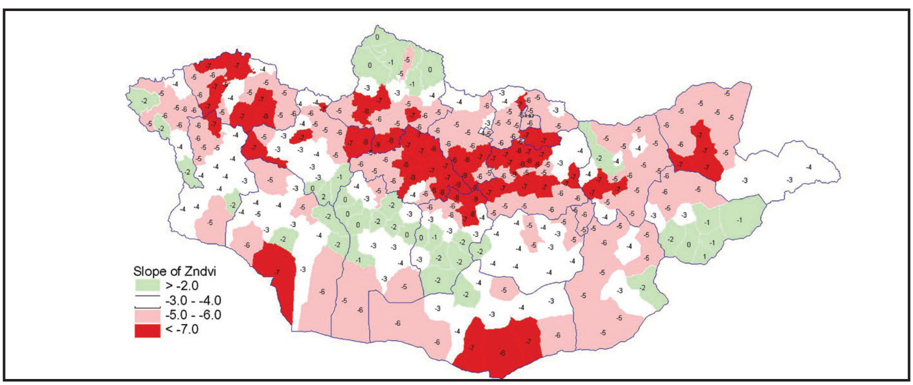

Figure 9: Slope of ZNDVI value, 1982 to 2003

2 $\overline{NDVI}$ i represents the long term average value of NDVI at point i.

Apart from looking at trends in the amount of pasture resources, the study has also looked at changes in phenology. As can be seen from the summary in table 3, the growing season is getting longer in almost all natural zones.

Table 3: Pasture vegetation (fenced) phenology phases dates change, days/1 year.

Natural zones	Vegetation species	onset	heading	flowering	maturing	senes-cence
Desert	Leymus	-0.77	0.73	-0.75	-0.36	-0.7
Desert	Stipa	-0.03	1.05	-0.32	-0.6	0.3
Desert steppe	Agropyron	-0.38	1.9	1.46	2.58	1.73
Desert steppe	Cleistogenus	0.75	0.46	0.02	-0.93	-0.52
Desert steppe	Leymus	-0.13	-0.94	-1.29	3.92	1.59
Desert steppe	Stipa	0.13	0.49	0.57	0.24	-0.1
Forest steppe	Agropyron	-0.57	0.16	0.31	0.39	0.43
Forest steppe	Festuca	-0.32	-0.04	0.26	0.15	-0.32
Forest steppe	Leymus	-0.53	-0.39	-0.78	-0.59	0.21
Forest steppe	Stipa	-0.51	0.78	0.4	0.12	-0.11
Steppe	Agropyron	-0.16	0.24	0.07	0.07	0.09
Steppe	Cleistogenus	0.16	0.33	0.46	-0.12	0.14
Steppe	Leymus	-0.18	0.04	-0.77	-0.68	0
Steppe	Stipa	-0.41	0.78	-0.22	-0.23	-0.08

Factors influencing pasture resources

Typically, the causes of land and pasture degradation are various. The Agency of Land Affairs, Geodesy and Cartography carried out a study on the state and quality of pasturelands in Mongolia and found that more than half of the pasture area was degraded to some extent (table 4). The table also shows the different reasons for the degradation and as can be seen from the table the main factor causing pasture degradation is overgrazing.

Table 4: Land degradation and its causes in Mongolia

Causes of degradation	Size of area, ha	Percentage of total surveyed area
Total pasture area conducted in survey, of which affected by:	58,282,362	
• autogenetic	279,516	0.5
• technological	130,328	0.2
• distribution of rodents	186,860	0.4
• overgrazing	15,985,413	30.1
• sand movement	1,934,894	3.6
• water erosion	181,724	0.3
• ravines	178,027	0.3
• polluted	2,085,454	3.9
Not used because of:		
• Over use	6,586,531	12.4
• Lack of water supply	1,288,708	2.4
Normal or not degradated	24,233,683	45.7

There are strong indications that the growing number of goats is rapidly adding to this problem. Goats are especially destructive to grassland vegetation as they frequently destroy the roots of plants. Over the past couple of years, the number of goats has increased significantly by 10 million. Currently, goats make up 47% of the total number of livestock in Mongolia.

These observations are further supported by the results from a study carried out within the NCAP project, which shows that, every year, the number of livestock is exceeding the carrying capacity of the pastureland in 135 to 180 *soums* (figure 10).

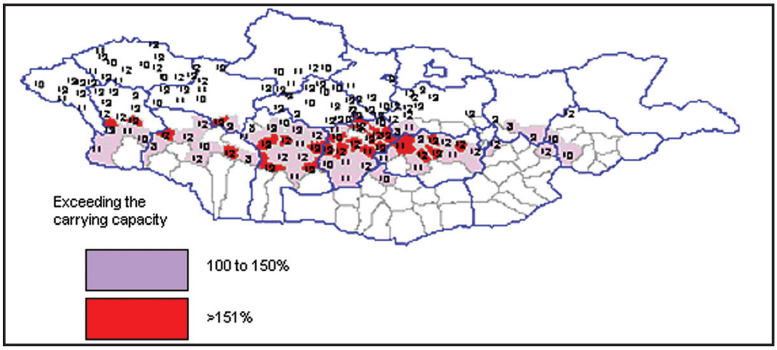

Figure 10: The exceeding of carrying capacity averaged for 1986 to 2003

Apart from overgrazing, it is recognized that other climate factors also play an important role in the quantity and quality of pasture resources. A study carried out examined the relationship between climate, soil moisture and vegetation and found, among other things, a strong correlation between July rainfall and vegetation growth. In addition, they also concluded that few but heavy rainfall events lead to less vegetation growth than more frequent rainfall events with less rainfall per event.

In a similar way, this study has calculated the differences in vegetation growth (using the NDVI as an indicator) between very wet, normal and very dry years. The analysis indicates that, in the case of a severe drought, the NDVI values decrease by 19% in Taiga, 30 to 55% in the forest steppe area, 55 to 78% in the steppe area and more than 64% in the desert steppe area compared to very wet years (figure 11). The results from this analysis show the important effect of rainfall amounts on vegetation growth with less rainfall leading to less vegetation and in certain cases no vegetation at all (NDVI<0.06).

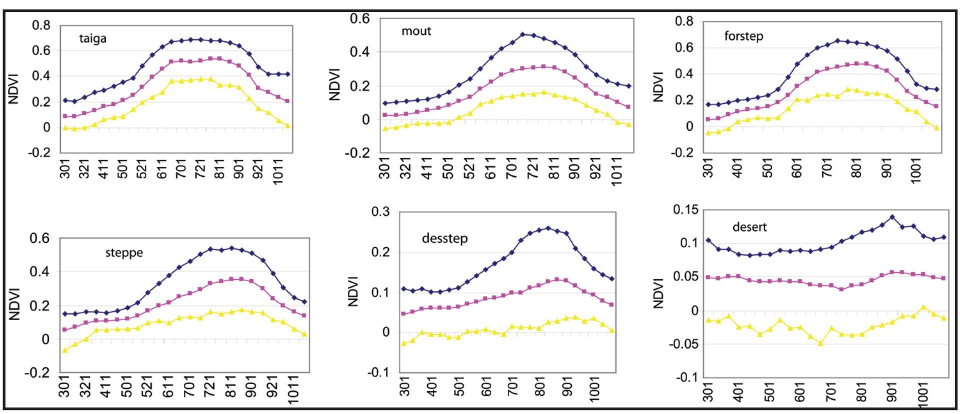

Figure 11: NDVI values for very dry (yellow), normal (pink) and very wet years (blue) in different natural zones in Mongolia

Also an analysis of the distribution of bare soil areas (i.e. no vegetation, NDVI<0.06) during dry and wet years clearly shows the effects of rainfall on vegetation. Figure 12 compares the bare soil area distribution during a wet year (1993 to 1994) and a very dry year (2001 to 2002). As can be clearly seen from this figure, the bare soil area is much larger during a very dry year.

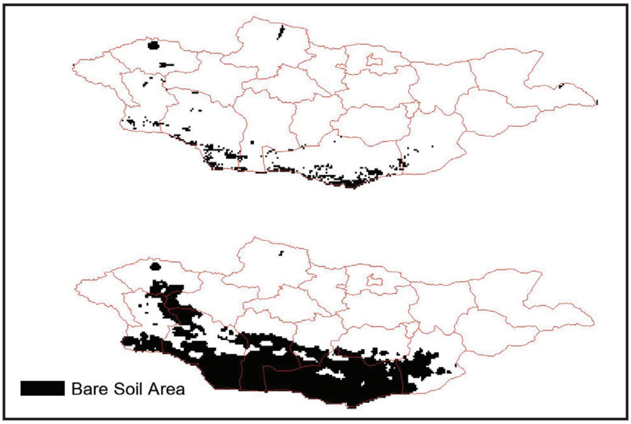

Figure 12: Bare soil area distribution in wet and dry years

Figure 13 gives the bare soil area as a percentage of the total pasture area in Mongolia and shows that in a very dry year like 2002, 25% of the total pasture area in Mongolia was bare. This situation severely reduces the availability of pasture resources for herding communities in the south of Mongolia and in certain cases this has forced herding families to abandon their herding lifestyle all together.

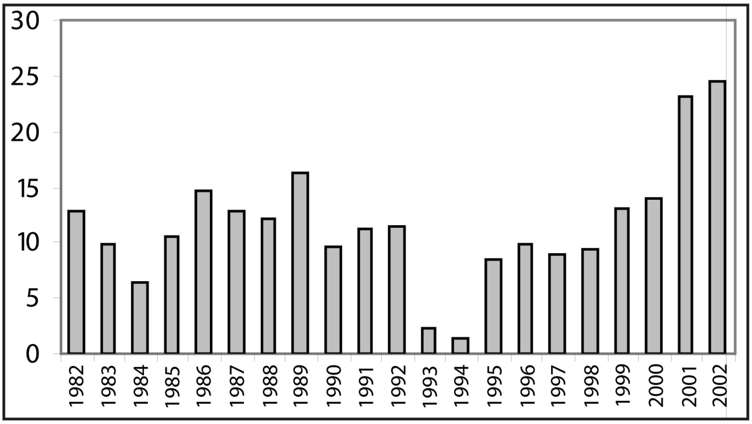

Figure 13: Bare soil area as a percentage of total pasture area

Impacts of climate change on pasture resources

Based on a detailed analysis of the relationship between the vegetation and climate conditions in the different natural zones, a vegetation growth index was developed.

Using this formula, threshold values of Qz were identified marking the point at which a shift of vegetation or natural zone is likely to occur. Future projections of temperature and rainfall in Mongolia were then used in combination with the threshold values to map the shifting boundaries of the different natural zones. The results are depicted in figure 14.

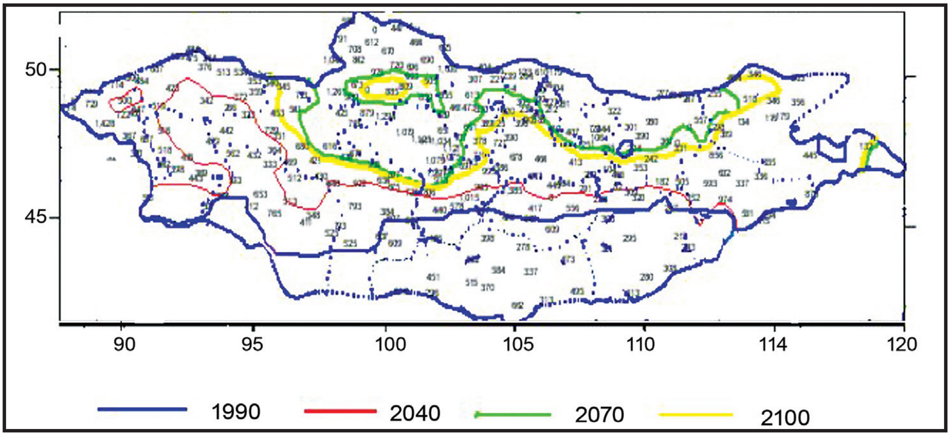

Figure 14: The shifts in the northen boundary of the desert based on threshold values of Qz. (The black figures represent the number of households).

Figure 14 shows that by the year 2070 northern boundaries of desert and steppe zones will move by 350 to 450km. This means that, over the next 60 years or so, the boundary of the desert is expected to move north at an average of 6 to 7km a year. It is clear that this will potentially have dramatic effects on the availability of pasture resources in the future.

3.3 Water resources

The total water resources of Mongolia are estimated at 599km^3 composed mainly of water stored in lakes (500km^3) and glaciers (62.9km^3). Annual river runoff and its groundwater contribution is estimated to be 34.6 km^3. Mongolia ranks 56th in the world in terms of water/capita/year and is defined as a country with limited or little water resources. Water resources are unequally distributed over the country: in the northern part of the country the available water per capita is 4 to 5 times more than the world average, in the southern part of the country; the available water per capita is 10 times less than the world average.

Historic trends in water resources

The latest state water inventory resulted in a count of 5,138 rivers in Mongolia of which 884 or 17.2 % had dried up. Similarly, in 2007 Mongolia had 3,747 lakes of which 1,189 were dry (31.6%). On average, surface water bodies in Mongolia had reduced by 25% in recent years.

Glaciers in Mongolia have been reduced by 30% since mid-1940. If this trend continues it is expected that glaciers with a depth of up to 50m will disappear by 2040, and glaciers with a depth of up to 100m will melt by 2050 to 2060. The largest glaciers with a depth of between 200m and 300m could completely disappear by 2070/2080 and 2090 respectively.

Several studies have been carried out that have tried to identify the reasons for the observed decline in water resources in Mongolia. For instance, the decline in river runoff has been explained by various factors, including a change in precipitation patterns with heavy rainfall events becoming more common (short and heavy showers are not contributing significantly to the soil moisture and consequently to the groundwater recharge), land cover changes due to human activities (land loses its runoff regulating capacity, there is less infiltration thus less recharge to the groundwater), loss of hydraulic connection between surface and groundwater, and finally change of river runoff and regime (direct flow has increased, while low flow period becomes longer).

Impacts of future climate change on water resources

In terms of the effects of future climate change on water resources in Mongolia, several studies have been carried out over the past years. These studies have already indicated that the water resources in Mongolia are very sensitive to even small changes in temperature and precipitation. Some of the main findings of these studies are briefly summarized here.

One study concluded that runoff in Mongolia will increase up to 2040 and will then start to decrease again. The study further suggests that the runoff peak flow will be about a month earlier in 2040 compared to the current situation. The appearance of ice phenomena in rivers is expected to be delayed by 3 to 10 days, while in spring period the ice cover breaking process is expected to start 5 to 15 days earlier than in the current situation. Equally, spring floods due to snow and ice melting are expected to start occurring.

Using the HadCM3 climate projection data, another study concluded that, by 2040, the permafrost area in Mongolia will be reduced by 30% and by 2070 to 2099 the permafrost area will have disappeared completely. As a consequence, the marsh areas will expand and start damaging settlements and infrastructure.

The latest studies on changes in evaporation, evapotranspiration, and runoff based on the A2 emission scenario show a significant increase in evapotranspiration during the 2020 to 2080 period and even the increase of runoff can not compensate such for this unbalance in the water cycle of the river basin. For instance, in Uvs lake basin in western Mongolia, the increase of river runoff is projected to be 10 times less than the expected increases in evapotranspiration. This again indicates that river basins will be much drier in the future.

The use of water resources by rural herding communities

Main sources of water for rural herders are different types of surface water as well as groundwater resources which are accessed through different types of wells. In a survey carried out among several herding families, it appeared that wells are becoming increasingly important due to the drying of surface water bodies. The herding families also identified wells as the best way to improve access to water in rural areas. The number of wells in rural Mongolia has varied over time. During the early years of the transition from a socialist system to a market-based system, many wells fell into disrepair and were left without an owner. Since early 2000, the situation has changed a little bit and about 2,000 wells have been repaired, 43 new wells have been drilled and by 2008 it is expected that 800 new wells will be built and several other wells are planned to be repaired.

Even though groundwater is playing an important role in the livelihoods of many herding communities, there is relatively little known about groundwater resources in Mongolia. The available data and information is scarce and certainly insufficient to support sound groundwater policies and the design of a well network for assisting rural herding communities. This study has looked at the groundwater resources on one site in the center of Uberkhangai province.

From the study, it appears that the groundwater table has significantly dropped between 1997 and 2006, probably due to changes in precipitation patterns and lack of recharge. Between 1997 and 2006, the groundwater table dropped 2m and according to this projection, the level may drop 5 to 6m by 2040. These are significant observations and further studies will be needed in order to better understand groundwater dynamics and availability.

3.4 Socio-economic indicators for climate change vulnerability

Vulnerability to climate change is not only a biophysical process, but also depends on socio-economic conditions and developments. This study has, therefore, also considered socio-economic indicators in order to understand the vulnerability of rural communities to the potential impacts of climate change.

Socio-economic conditions in Mongolia: understanding the baseline vulnerabilities

In Mongolia research of the livelihoods of the population has mostly been connected to the purpose of learning and understanding poverty levels at the national level. The results of these surveys divide the population into four groups: rich-middle, middle-medium, middle- poor and poor. According to 2006 census data, there are 170.7 thousand herding households in Mongolia of which 40% live below of the poverty line. Since 1996 the poverty of herding households has not decreased.

A more detailed survey, examined the livelihood conditions of rural herding households by examining five types of household characteristics:

X_1 – *income characteristics* (monthly income per person of household, monthly monetary income distribution, monthly monetary income & expenses)

X_2 – *immovable characteristics* (assets relevant to land and real estate such as a dwelling, its condition, livestock fences, water resources, wells, ownership of other immovable assets, and their value)

X_3 – *movable characteristics* (number of livestock, transport vehicles, valuable personal items, movable assets for use in the household)

X_4 – *characteristics of social indicators* (education and expenditure on education of herdsmen and other household members; social care (pension and health care); public services (health, education, cultural); infrastructure (distance from cultural services, health services and markets; electricity provision; veterinary services; communication provision; per capita daily caloric intake; access to credit; the environment of the living area)

X_5 – *characteristics' ability to adapt to external impacts* (socio-economic & climate change) (this is based on people's perceptions of their lifestyle, quality of life, opinions on unemployment and poverty in the area, and perception of the threats they face and the actions that need to be taken to reduce these)

Based on the analysis of these characteristics, households were grouped into four different categories: poor, lower-middle, middle and upper-middle. The results of the survey show that 60.7% of herding households live in poor conditions (see table 4).

Table 4: Livelihood conditions of rural herding households

	Total	Of which			
		Poor	Lower-middle	Middle	Upper-middle
Households	255	155	86	14	0
%	100	60.7	33.7	5.4	0

Table 5 also shows, for each of the household characteristics, the number of households per category of poor, lower-middle, middle and upper-middle. As can be seen from the table, 73.3% of the households are poor in terms of social position and none of the households can be considered upper-middle in terms of immovable assets or adaptation ability.

Table 5: Livelihood conditions of rural herding households according to different characteristics

Classification	Characteristics											
	Income (X1)		Immovable assets (X2)		Movable assets (X3)		Social position (X4)		Adaptation ability (X5)		Concentration of characteristics	
	house-holds	%	house-holds	%	house-holds	%	house-holds	%	house-holds	%	house-holds	%
Poor	151	59.2	175	68.6	151	59.2	187	73.3	120	47.1	155	60.8
Lower-middle	72	28.2	57	22.4	58	22.7	38	14.9	83	32.5	100	39.2
Middle	27	10.6	23	9.0	37	14.5	28	11.0	52	20.4		
Upper-middle	5	2.0	0	0.0	9	3.5	2	0.8	0			
Total	255	100	255	100	255	100	255	100	255	100	255	100

Table 6: Herdsmen's Livelihood Dynamic, 1990 to 2006, by thousand households

	1991-1990	1992-1991	1993-1992	1994-1993	1995-1994	1997-1996	1999-1998	2000-1999	2001-2000	2002-2001	2003-2002	2004-2003	2005-2004	2006-2005
<10	-11.4	-6.1	-10.5	-1.6	-3.1	-4.2	-3	2.7	2.4	-0.6	-3.3	-1.9	-3.7	-2.6
11-30	-16.4	-2.4	-12.2	-3.2	-3.2	-6.1	-0.9	4.5	2.6	-0.3	-3.4	-5.1	-2.1	-4.4
31-50	8.2	-0.7	-6.5	-1.7	-1.8	-2.7	-1.8	3.2	1	0.1	-3.8	-3.5	-2	-2.7
51-100	21.3	2.4	-2.9	-0.4	-1.9	2.3	-1.6	1.7	-2.9	-4.3	-3	-4	-2.7	-2.5
101-200	21.2	10.9	8.6	1.8	0.4	9.9	0.4	-8	-8.4	-5.3	1.3	0.5	1.6	2.9
201-500	5.2	8	10.9	3.7	3.1	1.6	1.4	-4.2	-5.5	-2.6	4.4	5.3	3.3	6.5
501-999	0	0.38	0.89	0.85	0.97	0.46	0.33	-0.85	-1.19	-0.25	0.7	1.5	1.2	1.9
1000-1499	0	0.01	0.04	0.09	0.14	0.09	0.2	-0.17	-0.25	0.04	0.1	0.3	0.4	0.7
1500-2000	0	0	0	0	0.01	0.02	0.01	-0.03	-0.01	0	0.02	0.04	0	0
2001<	0	0	0	0	0.01	0	0.01	0	-0.01	-0.01	0	0.0.2	0	0.1
less than 100 animals	1.7	-6.8	-32.1	-6.9	-10	-10.7	-7.3	12.1	3.1	-5.1	-13.5	-14.5	-10.5	-12.2

Climate conditions affecting baseline vulnerability

Herders are living under direct risk of weather and climate. Local officials and 97.6% of the herders consider climate change and environmental change a reality in their area[3]. When asked which aspects of their environment and climate had changed most significantly they named various elements including heavy snowfall, reduction of drinking water, frequent drought and *dzud* events, drying up of rivers and springs, reduction in hay making yield, reduction of feeding value of pasture land, sand movement and intensification of desertification. The herders also noted a decrease in the number of forage plant species, animal fatness and bodyweight, and consequently a reduction in the production of meat and milk as well as wool, cashmere and molt hair.

The importance of climate related events for rural herding households can be easily explained by the fact that herding households depend directly on their natural environment. For instance, when looking at the food intake by herding households, one realizes that livestock constitutes the main source of food in the form of meat and milk. Climate conditions that affect the survival of the livestock will therefore directly affect the food intake of the herding households.

Similarly, an analysis of the number of livestock per household during periods of favorable climate conditions compared to periods of less favorable climate conditions clearly shows the relationship between climate and household conditions. As can be seen from table 6, between 1990 and 1999, the number of households with small herds decreased for 8 consecutive years whereas the number of households with larger herds increased year by year. These developments can be partly explained by the introduction of private livestock ownership, but also by the favorable weather conditions during this period. During the *dzud* years of 1999 to 2001 many livestock died and immediately there was an increase in the number of households with small herds and a decrease in the number of households with larger herds.

4. Towards adaptation in Mongolia

Based on the results and findings from the studies and reports, it is recognized that urgent actions are needed to prepare Mongolia for the potential consequences of climate change. This project has, therefore, carried out two interrelated activities in order to move Mongolia towards adaptation. The activities that were carried out are:

- Activities in relation to building an institutional environment for adaptation; and
- Activities in relation to the formulation of concrete and specific adaptation measures.

Building an institutional environment for adaptation

Having realized that adaptation measures will be hard to implement without a strong and committed institutional framework, the project team has sought to contribute to the process of institution building and has actively engaged with policymakers at different levels to bring up the issue of climate change adaptation.

Developing a strong institution for adaptation was considered to be a necessary step because experiences from the past have shown that policy measures often only exist on paper and are rarely implemented because of the lack of institutional capacity, vague mandates and lack of financial resources. The National Action Plan for Climate Change in Mongolia, for instance, which was already approved in 1999, has not yet been implemented due to lack of financial resources and political commitment. This and other documents will need to be updated in order to make them compact, easy, executable and measurable.

3 Risk and development of Livestock sector, “Risk Study” working group, JEMP co., Ltd., February 2002

Therefore, the project has suggested the development of a permanent unit within the government, which will be responsible for climate change adaptation and will receive secured funding from the government budget. To this end, the project team has worked closely together with representatives from the Mongolian Parliament to put together a draft resolution for establishing a Permanent Sub-Committee on Climate Change Adaptation. The draft has been introduced to the Permanent Standing Committee for Food, Agriculture and Nature and Environment of the Mongolian Parliament.

Apart from formulating a draft resolution for establishing a Permanent Sub-Committee on Climate Change Adaptation, the project team has also worked with the office of the President to include climate change adaptation into the 'MDG-based Comprehensive National Development Strategy', which was ratified by Parliament on the 31st of January 2008. Due to these efforts, chapter six of the strategy now has a very strong focus on climate change and climate change adaptation.

Formulating adaptation measures

Many of the adaptation measures that have been formulated in the past, are often characterized by their generic approach and in many cases little thought went into how they can be financed and implemented. Furthermore, adaptation measures are often formulated without taking into consideration other drivers of change. The discussions about climate change vulnerability, for instance, have caused a lot of discussions in Mongolia about whether or not the government should stimulate a shift from traditional livestock activities towards an economy based on farming. However, traditional livestock activities are not only under pressure from climate change but are also influenced by other socio-economic developments, such as the increased demand for cashmere. Without understanding these broader developments, it is hard to develop appropriate policies for dealing with the problems that people are facing.

Having recognized these issues, the project team has tried to formulate a set of adaptation measures that are specific, realistic and clear in terms of space and time, and most importantly, they are executable and measurable. The formulation of adaptation measures was further guided by a couple of principles. Firstly, the project team is convinced that traditional livelihoods based on livestock herding will continue to exist in the coming decades. Consequently, the starting point for the formulation of adaptation options is the traditional herding communities. Secondly, rather than focusing on livestock as a point of departure for developing adaptation measures the project team has sought to bring the herders to the centre of the discussion and has tried to design adaptation measures that can support their communities.

To support and complement the list of adaptation measures, the project team also developed a climate change adaptation model for herders. Core ideas of the model include:

- designing comfortable mobile accommodation for herders with secured water, energy and communication supplies and which meets basic sanitation requirements;
- creating a network of "water filling stations" similar to the network of petrol stations in other parts of the world;
- cultivating fodder for animals in areas with favorable climate conditions and developing a forage distribution system, possibly linked to the "water filling station" network; and
- increasing and supporting education, awareness and information exchange capacities of herders.

5. Conclusion recommendations

Studies carried out under the second phase of the NCAP in Mongolia, have convincingly shown that climate change impacts will have significant effects on the natural resource base of rural households in Mongolia. Changes in temperature and rainfall patterns combined with an increase of extreme events are projected to have negative impacts on both pasture and water resources in Mongolia. This is expected to further add to the economic hardships that many of the rural households are already experiencing. The studies have also calculated that, by 2070, the northern boundaries of the desert zone will have moved north by 350 to 450km, making economic livestock keeping nearly impossible in large areas of the country.

Based on the results and other experiences from the NCAP project in Mongolia, the following strategic recommendations and suggestions for further research were developed.

Policy recommendations

One of the main lessons learned from this project was that, without a strong institutional environment, it is very hard to implement any adaptation policy or measure. Consequently, this project has sought to contribute to the establishment of a Permanent Sub-Committee on Climate Change Adaptation as part of the Standing Committee on Food, Agriculture and Environment of the Mongolian Parliament. At the time of writing, the proposed sub-committee had not yet been approved. Hence, it is recommended that further efforts are taken to realize this aim.

In addition, and based on the observation that there are already a significant amount of policy documents relevant to the issue of climate change adaptation available, it is also recommended to revise and update existing policy documents and to start enforcing existing laws and regulations.

Finally, more efforts need be made to create a more favorable financial and economic environment for herding households so that some necessary investments can be made for coping with the adverse impacts of climate-related hazards. Possible ways of improving the financial and economic environment include:

- the establishment of favorable long term loan conditions;
- the creation of clear rules for property and ownership;
- facilitating the establishment of small enterprises; and
- the development of insurance packages for climate related risks.

Suggestions for further research

One of the key outcomes of this project has been the development of downscaled climate data using the PRECIS model. As was mentioned before, one should, however, be careful in interpreting the results from only one climate model because of the uncertainties that are inherent in all the existing climate models. Recently, many authors have started to argue for the use of multi-model approaches which combine the results from many different climate models and, as such, proved a better basis for decision-making. More downscaling work needs to be done in Mongolia in order to start using the multi-model approach and to provide better climate information to decision-makers.

The studies carried out under the NCAP project in Mongolia include both biophysical and socio-economic studies. In the end, however, it proved difficult to combine both the biophysical and socio-economic information in order to better understand the vulnerability of rural households to climate change. Further research is needed to better understand these dynamic interactions between biophysical and socio-economic systems and to link both systems.

One of the key areas that has received insufficient attention so far in the climate change community is the impacts of climate change on the availability and distribution of groundwater resources in Mongolia. As many rivers are drying up, more and more rural households are starting to depend on groundwater resources. A better understanding of the availability and distribution of groundwater resources will be necessary in order to improve the management and use of these valuable resources by rural herding communities.

Climate Change Adaptation in Mozambique

Telma Manjate, Angela Abdulla, Katia Taela, Boaventura Nuvungu, Boas Cuamba, Zaina Gadema, Leanne Wilson, Jo Rose and Phil O'Keefe

1.0 Background

Adaptation efforts in Mozambique, organized through the climate department in the Ministry for the Coordination of Environmental Affairs (MICOA), have been stimulated by NCAP activities as well as the emergence of an improved, effective pre- and post-disaster planning capacity in the reorganized administration of the National Institute for Disaster Management (INGC).

A wide range of issues have been covered with substantial production of policy papers. Distribution of these papers initially only occurred within government offices rather than reaching a wider range of concerned stakeholders such as local authorities and NGOs. The first national communication to UNFCCC was posted in 2006, with support from NCAP, and there is active debate on what the second national communication should contain based on the adaptation work described in this chapter. To consolidate the link with the INGC, there has been a series of provincial level disaster planning seminars under the joint ownership of the MICOA and the INGC.

The program began with an overview of the capacity to respond to natural disasters in Mozambique. The conclusion of this first study was the need to build local resilience capacity at community level based on existing experience. Moving up the scale, there was need for sector planning, especially agriculture and water, to incorporate a level of risk calculation. At the national level, there was a need to integrate climate adaptation issues into pre-disaster planning. From local to national level, all of this had to be done by focusing on the groups who were most vulnerable to climate risk. There was also a need to organize the government and NGOs into effective pre-disaster planning.

Parallel to this review of capacity was a review of climate induced disasters from 1999 to 2005. This focused on exploring positive experience which could be used for the future. It reviewed the role of various agencies focusing particularly on the south and central region of Mozambique, the area most affected by tropical cyclones. It recognized that vulnerability was closely tied to economic capacity. The paper captured the changes in the INGC which has central responsibility for pre and post disaster planning. It recognized that there was need to use global warning systems, including FEWSNET. At provincial level, it was argued that pre-disaster planning was needed by joint exercises between MICOA and INGC building on the positive experience in the Buzi locality and Sofala province.

The Climate Change Action Plan (NAPA) linked with the Plan to Combat Desertification (NAP) as well as the Strategic Plan to Conserve Biological Diversity (NBSAP). This was later updated to a specific plan that linked implementation of the 3 conventions to the poverty reduction strategy which was, and is, the Government of Mozambique's key economic development policy.

Mozambique has very little scientific information available at national level and, unsurprisingly, even less at provincial and district levels. One of the substantial efforts of NCAP Mozambique was to build a national profile of weather variation from 1860 to 2000. This showed a significant increase in temperature from 1980 onwards. More detailed data was provided for the 20th century based on 10 recording sites for the whole country. Rainfall in general showed a decrease, although the data was substantially distorted by the extreme flooding of 1999 and 2001.

One of the tasks completed was to look in detail at training requirements in order to complete the second report for the UNFCCC. Particular attention was paid to the agricultural sector. Three vulnerability reports were completed, one focusing on fisheries, one focusing on the coastal zones and one on the vulnerability of hydrological resources to climate change.

Significant effort was made to establish capacity for vulnerability analysis, largely through the University of Eduardo Mondalane. The initial results of these efforts are contained in this chapter.

1.1 Mozambique's Climate Regime

The country can be divided into four climatic regions, according to Köppen Climate Classification System.

- The northern and coastal regions, representing 60% of the total area of the country, have a tropical rain savannah climate.
- The inland parts of the central and southern sedimentary terrains, representing 28% of the country, have a dry savannah climate; this is most of the area south of the Save, and Tete province south of the Zambezi river.
- A small area around the Limpopo River (2%), in Gaza province, has a dry desert climate.
- The upland areas (10%) have a humid temperate climate; this covers areas in Gurué, Manica, Angónia and Lichinga.

In the south of the country, the mean temperature varies between 23°C in the coastal areas and 25°C in the interior, where the climate is drier. In the north, temperatures are in general higher, with an annual mean of 25 to 26°C in the low-lying coastal areas. In the higher areas, the temperature is lower: this is the case with the city of Lichinga in the far Northwest, located at 1,200m above the sea level, where the mean annual temperature is 18°C. In the central region of the country, the mean annual temperature is 25°C, but in upland areas it falls to 20°C. The average relative humidity is 71% in the coastal areas, and 64% on the border with Zimbabwe.

There is a great variation in rainfall between the north and the south of the country, and between coastal and inland areas. Along the coastal strip, mean annual rainfall is in the order of 800 to 1,000mm. South of Pemba there is a reduction to below 800mm, and between Beira and Quelimane, the figure is higher than 1,200mm. Because of the influence of the northwest monsoon, which affects the north and centre of the country, and the influence of the high altitude, this area has mean annual rainfall of 1,000 to 2,000mm, except in the region between Tete and Chemba, where just 500 to 600mm of rainfall occurs. The rainy season, which is a hot and wet period, runs from November to March, and is followed by a dry and relatively cold season between April and October.

1.2 Mozambique's Water Regime

The demand for water in Mozambique is divided between urban supply, supply for the rural population, irrigation, hydropower production, industry and mines, and forestry. In Mozambique, irrigation is the major consumer of water, followed by urban water supply, industry, and rural water supply.

Most of Mozambique's rivers run from west to east draining water from the high plateaus of central Africa to the Indian Ocean. Mozambique has 104 river basins that flow directly into the Indian Ocean. The coastal area is regarded as a single basin.

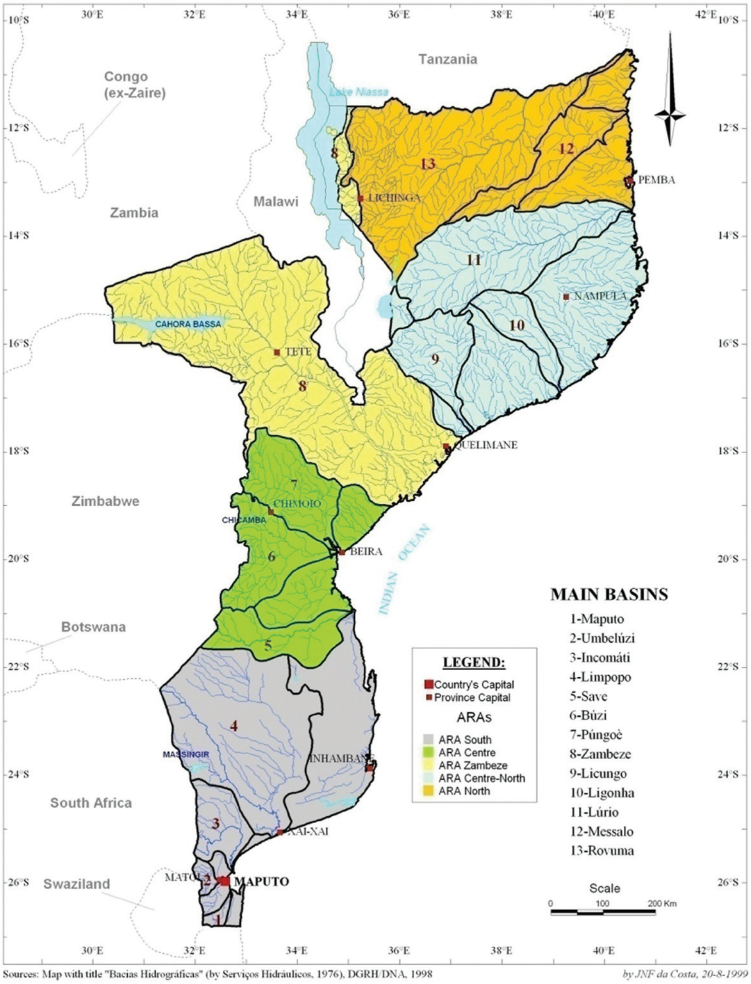

Figure 1: River Basins of Mozambique

With the exception of small rivers that drain into the coastal areas, most of the rivers have a torrential regime, with high levels of water for three to four months and reduced flows for the rest of the year. The basins south of the Save River mostly consist of the terminal sections of international rivers, such as the Maputo, Umbeluzi, Incomati, Limpopo and Save. These basins are characterized by reduced runoff coefficients, heavy intrusions of salt water at the river mouths (reaching more than 50km into the interior), broad and shallow valleys, with reduced storage potential, and consequently heavy evaporation losses and extensive flood plains.

In the centre of the country the basins are almost all located within Mozambique. Buzi and Pungue are the international river basins in the centre. The rivers rise in the mountainous border areas and gradually descend to the sea, where there is also heavy salt-water intrusion. These rivers have a more permanent runoff regime compared with the rivers in the south, not merely because of the climatic differences between the regions, but also because of the increasing use of water upstream in the international basins of the southern region.

The Zambezi River flows across a narrow valley near the border, and between Mpanda–Nkuwa and Tete, after which the river widens and becomes a vast delta as it approaches the Indian Ocean.

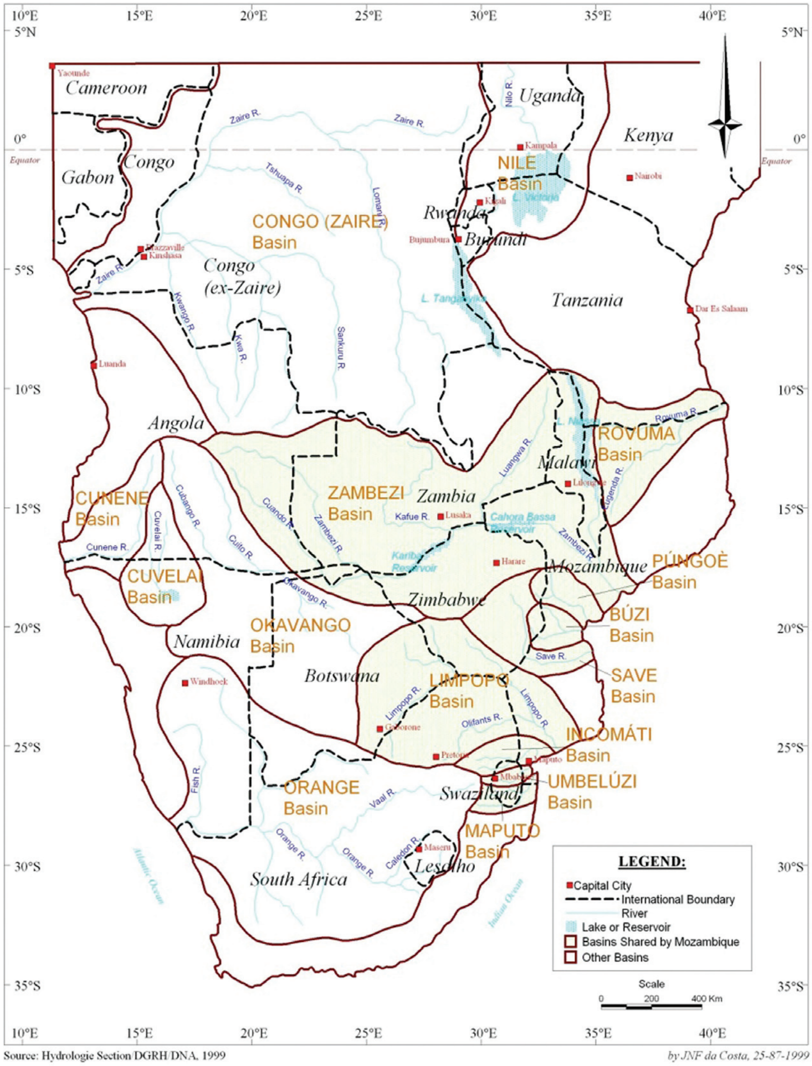

Figure 2: The International River Basins of Mozambique

This river has a large hydropower potential in the upstream reaches, and further downstream, extensive areas of land that can be irrigated, which are, however, subject to flooding.

The rivers of the northern region rise in the plateaus and the mountains. Some of the rivers have important waterfalls and steep slopes, with good hydropower potential, the Lurio, Licungo, Messalo and Ligonha in particular. The Rovuma River forms the border with Tanzania. The surface waters are the country's main water resource. Mean annual runoff is estimated at 216,000 million m^3, of which only 100,000m^3 originates from rainfall inside Mozambique. The remainder originates in countries upstream: this figure is falling with the increased use of water in these countries. The basin of the Zambezi River represents almost 50% of the surface water resources and about 50% of the flow from countries located upstream.

In Mozambique, the availability per capita of surface water resources is currently about 5,556m^3/inhabitant/year, taking into account only the runoff generated in the country, or 12,000m^3/inhabitant/year, including the flows from neighboring countries.

Compared with other parts of the world, Mozambique has a shortage of water. Indeed in Mozambique per capita water availability (excluding the inflows from countries upstream) is below the African average. This situation is worsened by the geographical and seasonal distribution of the water in the country, which results periodically in serious droughts in some parts of Mozambique, in addition to regional droughts covering all of southern Africa.

Three hydro geological formations can be identified in Mozambique, which coincide with the three main geological formations:

- Aquifers related to the geological formations of the Crystalline Complex (Palaeozoic and Pre-Cambrian);
- Aquifers occurring in the Karoo formations;
- Aquifers related to the post-Karoo formations (Mesozoic, Tertiary and Quaternary).

Ground water is the main water source for supplying the rural areas. To this end boreholes and wells with manual water pumps are used, but these have a limited capacity particularly for irrigation purposes. The hydro geological conditions of Mozambique make it possible for these systems to be deployed across the entire country, with some exceptions in the area of the crystalline complex or where the ground water is at too great a depth for the use of hand pumps. This is the case in the interior of the Gaza province and the far south of Manica province, where the aquifers are at a depth of over 100m.

Ground water is also used to supply some of the major cities – Pemba, Tete, Quelimane, Xai-xai, and Chokwe – as well as smaller towns (Ilha de Moçambique and Manhiça, among others). The use of ground water, however, is sometimes hindered by low water quality, caused by salt-water intrusion in the coastal areas, ancient marine intrusions, or contamination from the discharge of effluent. In substantial areas of the interior of Gaza and Inhambane provinces, as well as in the coastal strip of Zambézia province, the ground water is unfit for consumption due to high levels of salinity.

1.3 Impacts of Climate Change on Hydro Resources

According to the IPCC Fourth Assessment Report (AFR) climate change will lead to decreasing water availability and increasing drought in mid-latitudes and semi-arid low latitudes, with negative impacts on ecosystems. Hundreds of millions of people will be exposed to increased water stress. By 2020, between 75 and 250 million people in Africa are projected to be exposed to increased water stress due to climate change. In some countries, yield from rain-fed agriculture could be reduced by up to 50%.

Work done by the INGC, shows that the Limpopo river basin is one of the most vulnerable to flooding in the country. The Limpopo basin is the second largest of the nine international basins in Mozambique. It has no large dams to control the flow, which makes it highly vulnerable to the extreme precipitation occurring upriver in South Africa, Botswana and Zimbabwe. This basin is also vulnerable to drought: a large part of the basin receives less than 500mm precipitation each year. In the Pungwe river basin, dry conditions will get drier; there will be less water available for water supply, irrigation, and hydropower production; there will be a change in living conditions for fish in the rivers; the agricultural production season will get shorter; there will be a decrease in crop yield for rain-fed agriculture and an increased demand for irrigation, which imposes a need to choose suitable crops and to secure livestock fodder; there will be a risk of poor water quality due to low dilution when there is less water in the rivers; and finally there will be difficulties for the infrastructure in Beira City and other coastal settlements due to higher sea water level. For water sector adaptation, there is a need to prepare now for reduced water availability.

Historically Mozambique is the country most affected by natural disasters in the southern African region. According to the world report on disasters, more than 8 million Mozambicans have been affected by natural disasters in the last 20 years. Mozambique registered a total of 53 disasters in the last 45 years, representing in average 1.17 disasters per year. These disasters displaced 500,000 people, destroyed essential infrastructure and caused significant negative impact on the national economy.

1.4 The Impact of Drought and Flood

Drought is a common phenomenon in Mozambique, where accumulated impact is greater than flood. Drought occurs in cyclical time frames of 7 to 11 years. The 1991 to 1992 droughts were the worst in recent years, affecting a large area of southern Africa.

Climate events such as the floods of 2000 and 2007 have undone years of development efforts and the adverse impacts of climate change may further slow Mozambique's development. The recovery costs following recent climate extremes (table 1) provide an indication of the magnitude of the annually occurring damages. In Mozambique annual growth was estimated at only 2% after the devastating floods in 2000, having severely declined from 8% beforehand.

The National Institute of Meteorology (INAM) has analyzed the risk of drought on the basis that 500mm of rainfall is the minimum acceptable for rain-fed agriculture. Figure 3 shows areas of vulnerability for droughts based on this analysis. The southern parts of the country are most at risk.

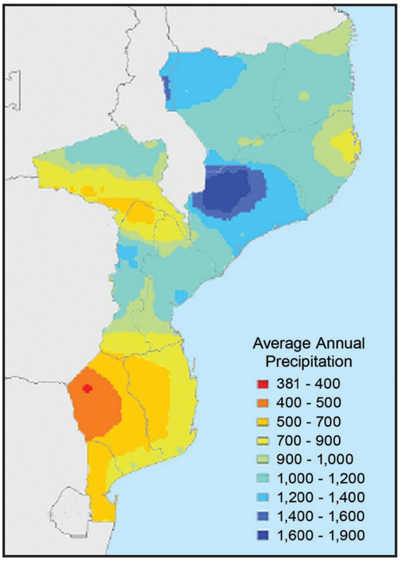

Figure 3: Annual average rainfall (mm)

Floods in Mozambique are due to both internal rainfall and water flows from neighboring countries as a result of precipitation in the upstream countries, frequently linked with inefficient management of dams. Although floods have negative impacts, they are also part of an ecological regenerative cycle, bringing nutrients to the soil, increasing agricultural productivity and replenishing groundwater.

There are 4 classes of flood vulnerability defined in the country:

- The risk of lowest level flooding is 1.7 million ha at an altitude of less than 20m above sea level, and up to 10km from the major hydrographical basins, representing about 6% of the national coverage. These areas can be inundated in years of medium to good rainfall;

Table 1: Recovery costs following climate impacts between 2002 and 2004.

Province	Rural Poverty	Recovery costs (thousand USD)								
		Droughts			Floods			Cyclones		
		2002/ 2003	2003/ 2004	2004/ 2005	2002/ 2003	2003/ 2004	2004/ 2005	2002/ 2003	2003/ 2004	2004/ 2005
Cabo Delgado	64.8	2,324	113	50	231	2,385	76	589	589	82
Gaza	61.0	2,222	8	208	903	2,757	707	419	1,548	373
Inhambane	84.7	8,199	182	27	894	329	866	1,504	75	8
Manica	32.0	1,715	248	73	233	1,303	145	0	85	80
Maputo	83.0	4,523	9,095	285	576	4,873	281	380	60	312
Nampula	58.7	4,032	117	438	529	1,166	94	4,998	2,836	738
Niassa	49.7	1,587	93	35	448	0	0	0	0	0
Sofala	40.8	1,185	970	250	191	806	1,028	434	1,300	709
Tete	57.8	2,276	2,081	2,191	90	83	3,160	0	0	0
Zambezia	45.0	4,695	521	819	987	844	1,786	666	442	1,019
Total	55.2	32,756	13,428	4,376	5,082	14,456	8,143	8,991	6,935	3,321

- The risk of the second level is defined for altitudes between 20 and 50m above sea level, representing 2.7 million ha, some 9.6% of the total land area;
- The third level risk is defined for altitudes between 50 and 100m above sea level, with 10km proximity of the main rivers, representing almost 4 million ha, some 14% of total land area;
- The fourth level risk is less likely to occur than the other three types, and will have effects in years in which floods risk is associated with waters coming from regional rivers.

Figure 4 shows areas at risk of flooding in Mozambique.

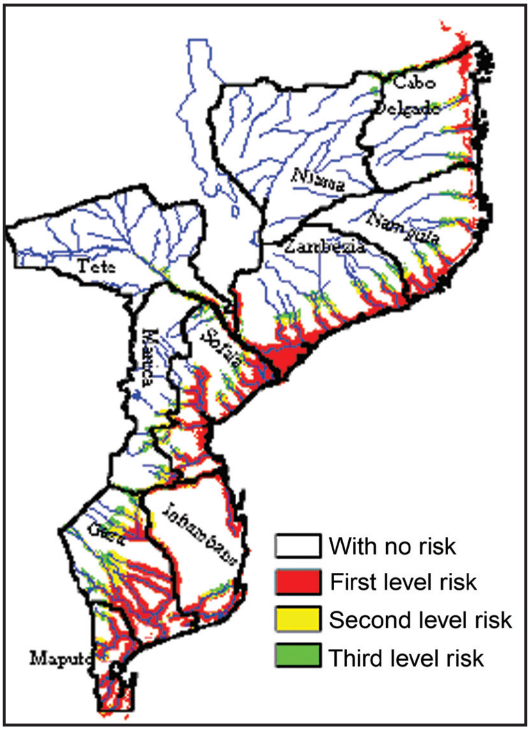

Figure 4: Areas at risk of flooding in Mozambique

According to the latest IPCC Fourth Assessment Report, the region of southern Africa will experience less water availability. The little rain expected will be available in very short periods. These situations will lead to both floods and droughts. The country has to learn to live with both phenomena.

Therefore there is a need to adopt proactive actions to these natural disasters before, during and after their occurrence. Major adaptation measures to be adopted can be summarized in short, medium and long term categories:

Short Term

- Building awareness of the relevance of climate change in development pathways, ensuring that climate change is recognized as relevant and an urgent priority across sectors;
- Reinforcement of the early warning mechanisms;
- Reinforcement of institutions dealing with climate change adaptation and disaster management;
- Building of technological adaptation through construction of dams for water control and storage, use of groundwater resources, harvesting of rain water, among others;

Table 2: Climate-Impact Matrix for MDG 1 'Eradication of extreme poverty and hunger'

MDG 1	Impacts of climate variability and change	Currently exposed areas	Affected social groups
Eradicate extreme poverty and hunger	*Current climate variability:* • Straining food security due to reduction or failure of agricultural production • Reducing peoples' livelihood assets, including housing, education centers, health provision sanitation supply and road infrastructure as well as the access to water • Tying up work force due to climate-related diseases • Reducing income opportunities *Future climate change:* • Straining food insecurity as a result of high flood and erosion risks for the majority of agricultural areas • Destroying maladjusted infrastructure, e.g. housing, roads, education and health centers • Impeding economic development due to destroyed productive assets and diseases • Posing a potential disincentive for investments in high risk areas	*High drought exposure:* Main areas of Maputo and Gaza and parts of Cabo Delgado, Inhambane, Manica, Nampula, Sofala and Tete *High flood exposure:* River valleys and coastal zones: Inhambane, Gaza, Maputo, Sofala, Tete and Zambezia *High cyclone exposure:* Coastal zones: Inhambane, Nampula, Sofala and Zambezia *High exposure to food insecurity:* Gaza, Inhambane, Niassa, Sofala, Tete and major parts of the remaining provinces	• Remote rural communities • Smallholders • Women and girls are more severely affected

Medium Term

- Mainstreaming climate change into development, enabling climate change issues to be integrated into different aspects of development planning;
- Reinforcement of scientific and technical capacity in climate change issues, to inform development policies and plans;
- Reinforcement of the capacity of forecasting climate patterns up to several months into the future, in order to enhance the capacity to respond to disaster situations;
- Expansion of the hydro meteorological network and introduction of modern technologies for data collection, transmission and processing;
- Computerization of hydrological databases and publication of the hydrological yearbooks, including systematic and regular exchange of information with neighboring countries.

Long Term

- Translation of scientific information into a format that is applicable to practical action by
- different stakeholders;
- Building of institutional receptivity across different sectors and organizations to receive such information;
- Undertaking of comprehensive studies of water resources, both surface and ground, covering the different aspects, like physical, ecological, and salt intrusion issues, among others;
- Promotion of the use of water desalination technologies for both sea water and water from boreholes, which in many cases have a high salt content in arid and semi-arid areas.
- Little progress has been made in relation to the MDG 1 (eradication of extreme poverty and hunger), which primarily targets the 86% of the Mozambican population living in rural areas.
- As a result of the combination of the high exposure to climate events, the high sensitivity and the low adaptation level, climate events have already severely affected poor rural communities.

While climate is not directly addressed in the MDGs, the examples above show the difficulties with attaining the MDG 1 given current climate variability. Moreover, climate change is posing further challenges to livelihoods and future development progress may be impeded by the increasing frequency and intensity of climate extremes.

2.0 Vulnerability Studies in Maputo Province

Maputo province covers an area of 26,058km^2 and is located in southern Mozambique. The province consists of eight administrative districts. Figure 5 shows the locations of three of the study sites which are the Moamba, Marracuene and Matola districts. Guijá is approximately 300km north of Maputo city. The main languages in the study areas are Changane and Portuguese.

The methodology copied the vulnerability survey protocol of Tanzania which is described in more detail in the Tanzanian chapter. There was training in the delivery of the survey instrument for university staff and graduate students. The initial surveys were done immediately around Maputo and then the MICOA conducted surveys further into Maputo Province.

Albazine

Albazine (Distrito Urbano No.4) is around 16km north of Maputo City and approximately 10km from the coast. There is no population data available for Albazine. There is a thriving market and a well-stocked local grocery shop in Albazine, and relatively good transport links to Maputo city (compared to Tenga and Marracuene). There are treated domestic water supplies in Albazine which cost between 51 to 100,000 MZM per month[1]. There is a combination of large and small agricultural landholdings in Albazine which are served by an extensive and well maintained canal system. The majority of local household food production is for sale in local markets as well as for domestic consumption. The main crops grown include bananas and sugar cane (which are vulnerable to high winds), as well as maize, carrots and vegetables. Fish and sea produce are brought from the coast to be sold in Albazine.

1 £1 equals 47,745MZM as of 21st April 2006.

There is a railway line through Albazine and a local hospital as well as a malaria spraying program every 3 months. There are lots of chapas (local mini-bus taxis) between Albazine and various locations in Maputo city, it costs around 7,500 MZM to get to Maputo in a chapas. Though the quality of the roads is highly variable, there are tarmac roads into Albazine and a mixture of tarmac and dirt roads within the district.

Guijá

Guijá district is situated in Gaza province 23º50'S and 24º50'S and between 32º25'E and 33º40'E approximately 300km north of Maputo city, and about 60km west of Xai-Xai, capital of Gaza province. Guijá has a semi-arid climate with an annual average temperature between 25 and 26°C, and annual average precipitation levels of 400 to 600mm. There are over 50,000 people, living in an area of 4,207km^2. Population density is estimated to be 17km^2 based on the 1997 census.

Marracuene

Marracuene is a riparian area around 32km north of Maputo City, located at the mouth of the Inkomati River. The 2006 projections for population size in the Marracuene district estimates figures at 50,263, with a population density of 67 people/km^2. There are 45 public schools in the district and 8 health posts. There are several markets in Marracuene where it is possible to buy domestic products. Concrete houses with gardens were constructed in Mumemo after the devastating floods of 2000 to rehouse, both locals and people from other areas. There are both small and large landholdings in Marracuene as well as a significant fishing community which totals 6% of the entire district population2. The majority of local household food production (crops, livestock, and fish products) is for sale in local markets as well as for domestic consumption. There are treated water supplies in Marracuene that cost around 20,000 MZM per month for the community pumps. There is a relatively small but important tourist industry in Marracuene including a ferry which goes to Macaneta beach several times a day. There are a number of cafés and pubs on the way to the ferry crossing.

Though the quality of the roads is highly variable, there is a good quality tarmac road into Marracuene from Maputo city and a mixture of tarmac and dirt roads within the district. There is a railway line and chapas to Maputo, but not many chapas travel locally within Marracuene. There are also small boats (12 people maximum) that transport people to Costa do Sol (approximately 10km from Maputo city) which are cheaper than the chapas.

Tenga

Tenga is a rural area located 40km north-east of Maputo City and 28km south-east of the district capital Moamba. There is a projected population size for Moamba of 36,460 people, with a population density of 10 people/km^2. There are 62 public schools in Moamba and 8 health posts. The majority of people in Tenga depend upon "traditional wells" known as xilovo (seasonal wetlands) for drinking water. There are some constructed wells, but these dry up as the dry season progresses. There is only one permanent water source in Tenga which retains water during the dry season, a xilovo around the course of the Rio Matola, which is around 6km from the village. Other options include getting water from Machava which is 24km away.

The area depends upon rain fed farming for subsistence, with most households having only small plots of land to cultivate. A minority of farmers in Tenga occasionally use supplementary irrigation but this is extremely limited due to a lack of water. In Tenga, most people are subsistence farmers who grow cassava and peanuts that are relatively tolerant of dry conditions. Other food crops grown are beans (including the leaves), onions, pumpkin, broccoli, and cashews. Many farmers also have a small number of domestic fowl (chickens, pigeons, and/or ducks) and/or goats, mainly for domestic consumption. There are a few wild fruit trees in Tenga, such as massala, tinsiva, and maphilwa that are consumed locally and occasionally taken to be sold in Machava or Maputo.

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2 Based upon participants estimates

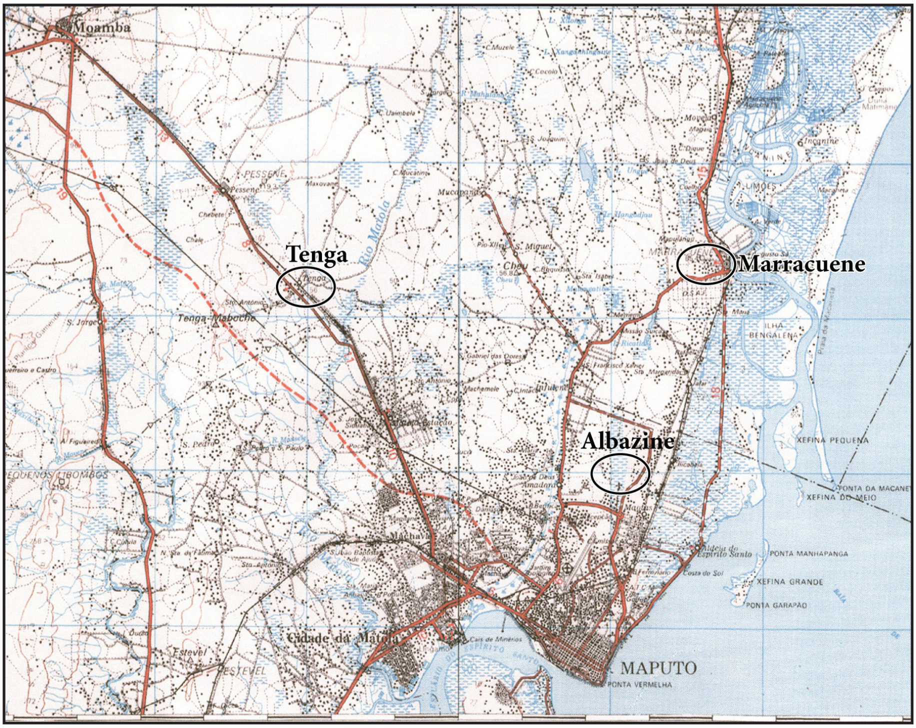

Figure 5: Map of Study Area

In terms of recreation, there is a small bar, and a cinema (a house with a TV) that costs 1,000 MZM (about 2p). The train stops daily (the Maputo – South Africa line) and buses come 3 to 4 times a day from Machava and Moamba. It costs around 9,500 MZM to get to Machava on the bus. The dirt road that leads into Tenga from Machava is severely eroded and impassable after heavy rain.

2.1 Findings

The majority of people involved in this study are chronically vulnerable to a range of stresses including climate risk. 70% of households are employed in the informal market and therefore have tenuous job/income security[3]. Only 15% of household members identified themselves as farmers though the vast majority of people interviewed either owned or had access to at least a small garden farm. Houses that are built with local materials are fragile and frequently damaged, and sometimes destroyed by heavy rains and tropical storms. This is especially the case for the rectangular houses that are less stable than round buildings. When it rains, thatched roofs leak. This is obviously very uncomfortable and prevents people from getting sufficient sleep. Such "low key" stress is clearly not a priority for intervention when food security issues prevail and need to be addressed, but nevertheless form a cumulative burden on vulnerable households. Houses built from local materials are less common in Albazine than in Guijá, Tenga and Marracuene.

Though the majority of households stated that a man was the head of the household, it was not specified whether this also includes families who are supported by migrant remittances. Gender divisions of labor within agriculture were not acknowledged by households in the study areas and

3 All quantitative statements are based upon surveys undertaken during September and December 2005.

initial observations did not contradict this perception. Children are expected to help with agricultural work when they are not at school, for example in the afternoons and/or weekends, though a minority of children do not attend primary school at all. Women and children are largely responsible for water collection. Women also hold almost sole responsibility for childcare, cooking, and health care within the family. Only one participant directly identified gender as an issue, because she did not know of any seasonal fluctuations in commodity prices since her husband controlled all of their money.

Malaria and gastro-intestinal diseases were the most common illnesses identified in all of the study areas.

There is dynamism as well as diversity in household composition in the study areas that may extend to include grandparents and other relatives at different points over the years. A third of households in all the study areas did not have personal possessions such as a radio, television, or bicycle. There was not a strong NGO presence perceived by the community in any of the study areas, though there is a food for work program in Tenga to build a road to Witbank (in South Africa). The majority of people in all the study areas identified the local church as the major community support institution, for example, in Mumemo and in Marracuene, the rehousing scheme is implemented by the local church. While there were public schools in each of the study areas, the vast majority of these catered only to grade 7 (primary level). In order to complete secondary education, families are obliged to send their children to travel great distances (from 16 to 40km).

Where banks or formal micro credit facilities exist in the study areas (there are none in Tenga), they are not used by the majority of people who either cannot open an account or cannot afford interest charges (even if they would be eligible for credit). Money may be borrowed from neighbors, friends, or family in exceptional cases such as illness or death of a family member. The only other circumstance in which someone would consider borrowing money would be to start up a small business. Xitique (estique in Portuguese) exists to a varying degree in all of the study areas. Xitique is the name given to a collective savings scheme between households. The xitique system requires that everyone in the scheme contributes a small amount of money each month and the sum of all these contributions goes to one member each month on a revolving basis. However, while most people agreed that it was present, the majority of people said they did not use xitique.

Common strategies employed to minimize climate risk were limited in all three study areas and included setting up small businesses to sell charcoal or other natural resource products (for example bamboo, thatch, wild fruits). This indicates that there are severely restricted opportunities to diversify income opportunities, particularly because these common strategies are employed simultaneously within the communities during periods of hardship (thus lowering the value of the products). Many older people in the study areas are able to interpret short-term weather patterns from cloud formations, and most people have access to the National Meteorological Institute radio broadcasts either directly or through neighbors. There was the perception, particularly from older people in Marracuene and Tenga that the predictability of the seasons is decreasing.

Albazine

In Albazine, the agricultural area covers both highland and lowland plots. Cash crops dominate in Albazine, including both large and small landholdings. However, when smaller producers go to Xiquelini (one of the local markets) business is not lucrative because there is strong competition with other producers (who come from as far away as Gaza province) who have larger volumes and higher quality products. Pests were identified as a major threat to agriculture in Albazine, and because pesticides are considered expensive, significant damage is often sustained.

Tropical storms were identified as a hazard for tall crops such as sugar cane and bananas. Flooding and waterlogging affect the lowland farm plots between January and March, which is significant because up to 20% of households have plots in the river basin. In Albazine, people identified xiloco as a coping mechanism to ameliorate the impacts of flooding. Xiloco is a system where people who have farms in the lowlands work on farms in the higher areas in return for food, clothes, or sometimes money. This is possible in Albazine because there is a relatively higher degree of socio-economic stratification (compared with Tenga for example), and therefore the xiloco system is important in maintaining local livelihoods. The last floods witnessed in Albazine were in 2002, although people did not require assistance to cope with this hazard.

Albazine is the only location where the majority of households surveyed possess 2 bedrooms, and almost half of the households surveyed had possessions such as a radio, television, bicycle, and/or sewing machines. Almost everyone who participated in the study considered that domestic water quality was good enough for drinking and cooking, and almost half of the respondents were able to collect water in an under 15 minute roundtrip from their homes. A small percentage of households receive both water and electricity. Charcoal is the most common fuel, though wood is sometimes used. Despite the relatively good transport network in Albazine, the majority of people surveyed do not use transport. The general perception of residents in Albazine was that there are hardly any opportunities for jobs outside agriculture or that the local wages are extremely low.

Guijá

The majority of the population of Guijá are women (43% are male), and typical family size is between 3 and 5 people. Almost 90% of families have built their own homes, which have 1 or 2 bedrooms. Approximately half of these are built using locally available materials. Houses made with wood and zinc, are more common than those built with blocks or bricks. Almost all households surveyed use gathered firewood to cook, and over 70% of households use paraffin for lighting. There are 150 boreholes with hand pumping systems in Guijá (110 are operational), and the majority of people get water from local wells or boreholes on a daily basis. The water is usually good for consumption, though more than half of households surveyed harvest rainwater for domestic purposes. Most households have access to a toilet or latrine, with 30% of households reliant upon going to the bushes instead of a latrine. Malaria and diarrhea are the most common diseases in Guijá. Most households prefer to go to hospital if possible when sick, though a minority mentioned the use of medicinal plants/local remedies.

Almost all families in Guijá practice agriculture, the vast majority of which is rainfed. Up to 30% of farms have an irrigation system. The main crops include maize, beans vegetables, cassava and peanuts. Only around 10% of families have access to animals or tractors for their farms, and almost 70% of people practice mixed cropping. Crops are perceived to be extremely susceptible to pest damage, with maize being identified as the most vulnerable crop.

At the time of the survey, households were buying seed stock because their stock was damaged by drought. Seed fairs had been established to assist in restocking, but these were not regulated. This creates serious sustainability issues because traders were coming from the Northern provinces and selling seeds very cheaply relative to local prices. Besides damaging the local economy, these cheap seeds are not particularly adapted to local environmental conditions. This means the cheap seeds are likely to cause a further failed harvest. Droughts started in 2001 and got worse in 2005. Local indicators of drought include ants, elephants, and the birth of more boys. Up to 80% of people required food aid during the 2005 drought. During times of scarcity, there are very limited options for economic diversification. Selling firewood in the informal sector, seeking wage employment on farms with irrigation systems, or migration to South Africa were the only stated options.

Almost half of the households surveyed live near the Limpopo River although there is no fishing industry in Guijá. Almost half of households had farms in the lowlands. Up to 30% of households were reached by the 2000 floods, which dominate local memories. Up to 80% of people required assistance with food and clothing, the vast majority of which was provided by NGOs and religious organizations. Almost everyone (90%) said they didn't have any advance warning of the floods, and many households lost livelihood assets such as housing, farm production, and livestock. Traditionally, good harvests on Marula trees are a sign of rains, but in the case of the 2000 floods, the opening of water control systems in the Republic of South Africa as well as heavy rains were attributed to be the cause of the floods.

Marracuene

The 2000 floods devastated large parts of Marracuene and there have subsequently been several rehabilitation activities, including the construction of houses and relocation of some people to Mumemo. There were major floods witnessed in Marracuene by older residents in the 1970s but the 2000 floods were the worst in living memory. They destroyed livelihoods, including houses, farms, livestock and tools, as well as rendering the roads useless for many months. The river is reported to be wider following the floods and is encroaching upon the land. Some people from Maputo city were relocated to Mumemo after the floods, and those who participated in this study commented that although there was no crime in Marracuene, transport was a problem.

There are several markets in Marracuene including an indoor market in Mumemo and a large outdoor market (around 150 vendors) on a Tuesday and Saturday at Mucauline. There is a small daily market down the hill on the way to Macaneta, adjacent to some local building suppliers. There are both small and large landholdings in Marracuene, with the smaller plots generally used mainly for household consumption. A risk management strategy identified by older people in Marracuene is to have more than one plot of land (for example one in the higher land and one in the riparian zone or another district) so that if crops fail due to flooding or lack of water, the other plot provides a level of insurance. However, this is not a strategy that can be readily employed by the whole community due to both financial and labor constraints.

Because of the proximity to the Inkomati River, floods can destroy agricultural production, though droughts are not considered to be a problem by the majority of households in Marracuene. However, a local shopkeeper commented that her business noticeably drops between March and July because there are not many crops in the fields, and people have no money to buy her products. There used to be a factory in Marracuene but this closed some years ago. There are some South Africans with businesses who offer local people jobs, but only on short term, temporary contracts. Opportunities for young people revolve around agriculture, fishing, cutting bamboo, or working at the local markets unless they have the resources and desire to migrate to other areas. A typical working day for a young woman begins at 04.00 when she buys bread and sets up her market stall that is open until 16.00 when she goes home to do chores, prepare the family meal and spend time with her children. Her father works on the farm during the week and she goes to the fields on a Sunday.

The majority of households have to purchase fuel, including firewood, whereas water can be obtained both from treated community pumps and charcos (seasonal wetlands). Over half the people surveyed can collect water from within a 30 minute roundtrip from their home, and three quarters of these consider the water quality good enough to drink. The majority of people surveyed do not use transport in Marracuene. If people need to travel locally, it is sometimes possible to get a lift for a small fee. Despite the significant fishing community, the majority of people are engaged in agriculture in Marracuene. This is partially explained by the fact that fishing is extremely dependent upon suitable weather conditions, and requires a fallow period from January to February, so many fishing households also have farms (which include cattle if they are prosperous), as well as engaging in other activities like seasonal building labor for example. Tropical storms are the biggest climate risk for the fishing industry in Marracuene.

Much of the fish products are sold to vendors who come from as far as Maputo and Manica to obtain fish and sea produce. One fisherman we spoke to has developed a business relationship with his buyers where they will take the fish to sell for three weeks and return at the end of the month to divide the profits. This has been sustainable for the past 5 years. It is not viable for the fishing community to sell only to local people who can usually only afford to buy small amounts. However, fish products are consumed by the family as well as sold. There was a fishing assistance fund set up by the government after the 2000 floods which loans money and/or equipment to fishermen so that they can rebuild their livelihoods. Not everyone is eligible for this fund, and those who utilize it repay 200,000MZM per month. Other fishermen have started to organize an association to discuss issues that affect everyone. For example because there are not many other job opportunities, some people continue to fish during the fallow period which will affect fish stocks.

Tenga

The quality of life in Tenga was defined entirely in relation to the rain because the vast majority of households are dependent upon rainfed agriculture. The only good thing people had to say about Tenga was that they could grow their own food. There is no sustainable source of drinking water and crops can fail due to a lack of rain, as well as due to flooding in the wet season. Xiloco was not identified as a coping mechanism by people in Tenga, because the majority of households in Tenga are too poor to maintain this system. A compounding factor is that the vast majority of farmers have relatively small plots of land and limited income generating opportunities. Most farmers had small livestock, although we observed four cows and one donkey during fieldwork. A local resident explained that in the past, people used to have cows, but during the post-liberation civil war the Renamo soldiers ate their livestock and most people still cannot afford to replace them. Most farmers said that the soils were good and only needed to be cleared in order to cultivate.

No households in Tenga have electricity or water connections to their houses, and the public wells are neither reliable nor sustainable sources of water. Collecting water is at least an hour roundtrip for most people in Tenga and only around half of the people surveyed consider that the water is of a good enough quality to drink. There is a local health post in the village where it is possible to buy chlorine to treat drinking water but this obviously depends upon the income of households as well as the availability of the stock[4]. Two years ago, UNICEF brought tankers of water to Tenga because of a chronic lack of water. Wood fuel is gathered locally, though charcoal and candles are purchased. It is difficult to obtain wood (that will light) if the rains are heavy. This is compounded by the fact that the road from Machava is impassable after a day's heavy rain, which is an obstacle to sourcing charcoal or kerosene.

Discussion on Vulnerability

The majority of the people within all the study areas are vulnerable to a range of climate risks. Chronic poverty erodes the resilience of communities to external pressures, which is further exacerbated by climate hazards. The key climate hazards that impact upon the three study areas are floods, tropical storms, and drought. Floods impede agricultural production and other employment opportunities and activities. Tropical storms damage houses and crops, and halts fishing activities. Drought contributes to both food and water insecurity in Tenga, while in Guijá there are serious "maladaptive" recovery mechanisms that contribute further to food insecurity.

However, it is difficult to draw direct causal linkages between climate variability and the impacts on livelihoods perceived by the communities. For example, in Tenga, people said that life was bad when there was drought because they can't grow crops and so they go hungry. However, the main strategies to cope with a lack of food production in Tenga are based upon selling wood, charcoal, and to a much lesser extent, unprocessed wild fruits. This requires up to 25km travel to places such as Machava or Moamba which is either expensive or exhausting (or both!) and there is both strong competition and limited demand for these products. Other strategies include selling labor in the informal sector that provides limited opportunities for insecure and poorly paid work. So it is fair to conclude that a lack of opportunity for alternative seasonal employment, combined with drought conditions greatly affects food security in Tenga. Additionally, due to a general lack of agricultural inputs in the production systems, declining soil fertility may be a compounding factor in declining

4 According to several respondents, the health post does not always have medicines in stock which means they have to be obtained from Maputo

food security during the drought periods. Intensifying agricultural production and improving post harvest storage, as well as improving the regulation of seed fairs would increase food security in all areas.

Limited opportunities for employment exist outside of agriculture which increases vulnerability to climate risk throughout all study areas. The strategies identified in Albazine and Marracuene rely upon socio-economic stratification within the community, for example xiloco cannot work if everyone is poor, and clearly having more than one plot of land is not a strategy that can be employed by landless people. This strongly demonstrates that social capital is not a panacea and is in fact eroded by chronic poverty. There is varied NGO activity in Marracuene, partially in response to rehabilitation after the 2000 floods, and there is a food for work program in Tenga. However, the only long term formal "grass roots" institutions within all three study areas were the local churches. These institutions should therefore at least be considered as potential partners in building community resilience.

There are much greater opportunities for income diversification in Albazine and Marracuene than in Tenga or Guijá because of their close proximity to several thriving markets. The higher proportion of durable houses and roads in Marracuene and Albazine also indicates relatively higher resilience to climate risks in both financial and physical terms. Environmental sustainability may prove to be an issue in the near future, particularly relating to the wood sourced for charcoal production in all the study areas, and local fish stocks in the Inkomati River. However, the fishing community is already actively seeking ways to resolve this issue.

It is obvious that the health situation for the majority of people in the study areas is extremely precarious, given their insecure access to employment and in some cases food and water. Malaria and gastro-intestinal diseases were the main health problems in all of the study. It is not surprising that HIV/AIDS was not mentioned by most of the research participants because of the widespread stigma attached to the disease. For example we were informed that people actively discriminate against HIV positive community members in Mumemo, partially because they receive special assistance from the church. However, HIV/AIDS prevalence is estimated at 16% in Mozambique and is therefore a serious threat to people already suffering from poverty.

The presence of the railway link to all of the study areas theoretically provides access to bigger markets (including South Africa). However, in order for people to be able to access bigger markets, there would have to be substantial support to communities in order to develop the production of appropriate value-added products.

The majority of people in the study areas are surviving in the short term. There is high vulnerability to climate variability in the short term because of a lack of income diversification opportunities and a heavy reliance upon the informal sector. With the exception of extreme floods, it is not useful to attribute this vulnerability solely to climate risk.

3. Conclusion

Work in Mozambique was extremely rewarding although it was done from a low information base. It was also true that state, provincial and district administrative structures were very weak and frequently under resourced in terms of both people and equipment. Nevertheless, the focus on pre-disaster planning, linking across state structures from the MICOA has proved to be a useful exercise in capacity building.

At the level of physical science data, the country remains inadequately served and thus finds itself trying to draw conclusions from broader regional analyses. There are, however, lead individuals around state, parastatal and university institutions who have demonstrated capacity at international and national level to complete the scientific requirements of UNFCCC reporting. Their ability goes beyond this formal reporting as demonstrated in this chapter. Their willingness to explore vulnerability as a key factor in the design of a local adaptation program offers hope for local solutions that address not only climate change but the broader challenge of poverty alleviation. There has been much to celebrate in Mozambique NCAP.

Planning for Climate Change in Overlooked Sectors: A Synthesis of NCAP Activities in Senegal

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1. Introduction

Since the creation of the United Nations Framework Convention on Climate Change (UNFCCC) at the 1992 Rio Summit, increasing attention has been paid to the fact that adaptation to climate change needs to be considered in coordination with what was considered to be the primary motivation of the original treaty, namely international negotiations to reduce global emissions of greenhouse gases. The rising profile of adaptation as part of the climate change dialogue is linked to at least two factors. Firstly, UNFCCC signatory countries from the developing world posited the compelling argument that while they had contributed little to the startling rise in greenhouse gas concentrations in the atmosphere, they were the most vulnerable to its potentially devastating impacts. The second factor emerged from the climate science community. Here the argument was that owing to the long residence time of greenhouse gases in the atmosphere and the fact that current concentration was already altering the global climate, there was little to be done in the near term to avoid climate change impacts.

Taken together these factors militated in favor of creating capacity within the developing world to adapt to negative impacts of a climate that would change because of the past actions of the developed world. Structure was given to conclusion at the 7th Conference of the UNFCCC Parties held in Marrakech, Morocco in 2001 with the approval of Decision 28 pertaining to "Guidelines for the preparation of national adaptation programs of action", or NAPAs. In parallel with the actions of the UNFCCC, various other actors were becoming active in the climate change adaptation arena, including the Government of the Netherlands which supported the Netherlands Climate Change Studies Assistance Program (NCCSAP), which in 2005 became the Netherlands Climate Assistance Program (NCAP).

The NCCSAP initiative was designed to enable developing countries to implement commitments under the UNFCCC, to create a greater awareness of climate change issues, and to increase the involvement of policy makers, scientists and the general public. The follow on NCAP intiative, launched in 2005, had the following aims:

- Assist participating developing countries to prepare, formulate, implement, and evaluate their policy in relation to climate change.
- Raise awareness of the problem of climate change in developing countries.
- Increase the involvement of policy makers, scientists, and "broad layers" of the population in the climate change debate in developing countries.

- Promote exchange of experiences between developing countries on climate issues.
- Impact the UNFCCC negotiating process through the raising of “burning issues”.
- Coordinate effectively between NCAP and similar international initiatives.

The first objective was intended to signal a new focus on making climate change information relevant to the actual formulation of policy, as opposed to the earlier initiative’s focus on understanding climate change vulnerabilities.

One of the initial challenges was to make this shift towards the policy arena operational and to this end the NCAP implementation team developed a series of 9 indicators against which progress in each of 15 NCAP partnering countries could be measured. One indicator set a specific benchmark that the ‘project has coordinated effectively with the NAPA process and other relevant on-going and/or planned initiatives’. One of the partnering countries, Senegal, placed this indicator squarely at the center of its own NCAP implementation plans. This made sense as Senegal was one of the early advocates for and participants in the NAPA process, and had become a resource to other Francophone countries in western Africa implementing their own NAPA programs. The Senegal implementation team was anxious to use the resources made available under NCAP to extend and deepen its own experience with the NAPA process, and in so doing they moved NAPA implementation in some interesting and unique directions, in particular by addressing economic sectors that had not previously been part of NAPA preparation in other countries. This paper attempts to synthesize some relevant insights from their experience.

2. The Senegal Context

As the farthest west nation on the Continent of Africa, Senegal faces squarely towards the Atlantic Ocean. Indeed the map of Senegal suggests the head of a lion watching out over the water (figure 1), with the Anglophone enclave of The Gambia its slightly open mouth. With a total surface area of 196,190km^2, Senegal has over 530km of coastline and the vast majority of the population, as demonstrated by the number of cities and the density of the road network, resides in the western third of the country. Towards the hotter interior, population centers lie along rivers that drain the Fouta Djallon Highlands in Guinea, principally in the stream networks of the Senegal and Gambia River systems.

Figure 1: Map of Senegal

Within this geographic setting, Senegal has been one of the most stable countries in Africa, electing a series of democratic governments since its independence from France in 1960. Following a painful economic restructuring in the early 1990s, the economic growth rate has been steady, averaging 5% per year between 1995 and 2007. Still, the per capita GDP in 2007 was only $1,700 per year. When viewed by sector, the service sector forms 64.4% of the economy, followed by industry (18.9%) and agriculture (16.7%).

These figures belie the fact that 77.5% of the labor pool is engaged in agriculture, many of whom are within the 54% of the population that lives below the poverty line. Three of the five primary exports from Senegal (fish, peanuts, petroleum products, phosphates and cotton) are derived from primary economic sectors.

In light of these geographic and economic realities it came as no surprise that when, soon after the COP7 meeting in Marrakech, Senegal embarked on its effort to develop a NAPA, with attention turning to defining climate change adaptation for the fundamental agriculture, water resources and coastal zone sectors. The next section of the paper describes this early effort starting with the general NAPA guidance and ending with an exploration of Senegal's ultimate recommendations in these three sectors.

3. National Adaptation Programs of Action

The original guidance from the UNFCCC regarding the NAPA development process was, probably by necessity, fairly general. This was after all a completely new initiative that was responding to an emerging, yet not completely understood, component of the international climate change negotiations. This section will trace out the evolution for the NAPA process from that initial guidance through to the initial implementation in Senegal.

a. General NAPA Background

According to Decision 28/CP.7 of the UNFCCC, NAPAs would serve as simplified and direct channels of communication for information relating to the urgent and immediate adaptation needs of the least developed countries. The hope was that formal NAPA documents would describe climate change adaptation strategies that would:

- Be easy to understand;
- Be action-oriented and country-driven; and
- Set clear priorities for urgent and immediate adaptation activities identified by the countries.

Within this broad mandate, countries were given the liberty to define specific criteria for selecting priority adaptation activities with several general categories, including:

- Level of degree of adverse effects of climate change;
- Poverty reduction to enhance adaptive capacity;
- Synergy with other multilateral environmental agreements: and
- Cost-effectiveness.

This last general criterion was important as there was an expectation in Marrakech, if not a commitment, that large greenhouse case emitting developed countries would financially assist the least developed countries to implement priority adaptation activities. Broad guidance was also given in Decision 28/CP.7 on the areas in which the ultimate selection criteria would be applied in order to identify priority adaptation activities. These included:

- Loss of life and livelihood;
- Human health;
- Food security and agriculture;
- Water availability, quality, and accessibility;
- Essential infrastructure;
- Cultural heritage;
- Biological diversity;
- Land-use management and forestry;
- Other environmental amenities; and
- Coastal zones and associated loss of land.

Here it is interesting to note that the list of potential areas within which priority adaptation activities would be defined relate to the natural environment and primary economic activities based on the country's natural resource base. If human health is interpreted as being part of the natural environment, then only two of the areas, critical infrastructure and cultural heritage, are outside primary natural resource based areas of human activity.

Decision 28/CP.7 also contained some broad procedural guidance that eventually led to the development of what became an eight step process towards the development of a NAPA. The steps were:

- Assemble a NAPA implementation team;
- Define goals;
- Synthesize available vulnerability assessments;
- Conduct a participatory rapid integrated assessment;
- Conduct public consultations;
- Define selection criteria;
- Rank potential adaptation activities; and
- Develop and submit NAPA project papers of selected adaptation activities.

Within the sideboards provided by these steps, it is very interesting to note how each country actually implemented its NAPA process.

b. Implementation Process in Senegal

Soon after the Marrakech COP, Senegal was one of the first countries to benefit from financial support provided by the Global Environment Facility (GEF), receiving a $195,000 grant to assist in the development of its NAPA. The stated goal of this investment was to assist Senegal in identifying urgent adaptation needs and priorities in the face of its vulnerabilities to climate change. Under this grant, NAPA activities in Senegal were organized into five phases, general organization, sectoral studies, public consultation, prioritization, and project formulation. Within these phases, the NCAP team elaborated the following steps, which echo those presented above:

- Establish a NAPA team;
- Synthesize impact studies, adaptation strategies, past consultations, and the projections of development frameworks already in place;
- Implement a rapid participatory evaluation of actual vulnerabilities and the risk of increasing exposure associated with climate change;
- Consult with the public to identify potential adaptation activities;
- Articulate potential NAPA activities in light of the consultations. Begin the process of selecting prioritization criteria;
- Rank activities and demonstrate their integration within national frameworks and strategic programs; and
- Prepare project documents for selected activities and submit NAPA.

It is interesting to note that while the guidelines for the preparation of national adaptation programs of action are largely silent to the need to organize the development of priority adaptation activities by sector, Senegal, like virtually all of the countries preparing NAPAs, quickly organized NAPA implementation around three primary natural resource based sectors, agriculture, water resources and coastal zone resources. For each of these sectors, consultants were hired to study sectoral vulnerabilities, their causes, and potential trends related to actual climate variability and human pressure in the exposure to the threats underlying these vulnerabilities. For this study, the consultants were instructed to add appropriate technical or policy adaptations that could be evaluated and prioritized during the public consultation step of the NAPA process. The addition of potential adaptations was intended to take into consideration experience related to the potential and limits of these adaptations gained at the local and national levels, and, where appropriate, internationally.

In order to complete this analysis, the NAPA team overlaid the administrative regions of Senegal with a map of the eco-geographic regions of the country (figure 2) to develop a general framework for geographically targeting priority adaptation activities that would emerge from the NAPA process. The groupings that emerged from this analysis are shown in table 1. While these groupings do not represent a perfect mapping of administrative zones into eco-geographic regions, the expectation was that they would serve to distinguish between locally promising adaptation activities. Equipped with the results of the scoping studies on agriculture, water resources, and coastal zones, and the framework for geographically targeting adaptation activities, four separate public consultation events were organized and conducted.

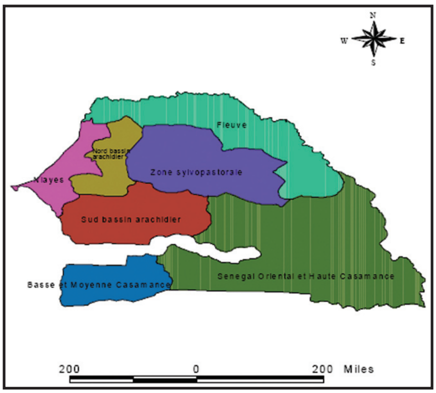

Figure 2: Eco-Geographic Regions of Senegal

Table 1: Distribution of Administrative Regions into Analytical Zones

Northern Region	Region of "Niayes"	Region of Peanut Production	Southern Region
Saint-Louis Matam Louga	Thies Dakar	Fatick Kaolack Diourbel	Tambacounda Kolda Zinguinchor

The public consultation workshops served to bring together representatives of the public sector, local administration, and stakeholders to review the suggested set of adaptation activities provided by the consultants and to develop a set of priorities. Multi-criteria analysis was selected as an appropriate method for ranking the adaptation activities. This decision was made because of the difficulty developing the information needed to carry out cost-benefit analysis, another option suggested in the NAPA guidelines, and because it allows for the ranking process to accommodate differing, perhaps even conflicting, values and objectives that can emerge from different stakeholders in a particular region.

In each of the four public consultations the following steps were taken to implement the multi-criteria analysis:

- Determine appropriate ranking criteria;
- Set the numeric importance, or weight, associated with each ranking criteria;
- Score each of the potential adaptation activities suggested by the consultants against these criteria according to their expected levels of performance;
- Sort the potential adaptation activities in order to define local priorities.

By implementing this procedure, the NAPA team in Senegal was able to arrive at a series of priority adaptation activities for each of the three chosen sectors in each of the target zones. These are described in table 2. From this list of priority adaptation activities, project papers describing the implementation steps and costs of a limited number of options were developed and submitted to the UNFCCC as the NAPA priority activities in Senegal. These were:

- Agro-forestry promotion
- Rational use of water resources
- Coastal zone protection
- Awareness raising and public education

These adaptation actions were all of a programmatic nature and were presented as general development initiatives rather than a specific project to be realized in specific places in order to reduce specific vulnerabilities to future climate change.

Table 2: Priority Adaptation Activities Identified from Multi-Criteria Analysis

Sector	Northern Region	"Niayes" Region	Peanut Region	Southern Region
Agriculture	Reforestation	Reforestation	Reforestation Enhance soil/ water	Reforestation
Water Resources	Micro-irrigation Rainwater harvesting	Water use efficiency Aquifer recharge		
Coastal Zones	Coastal protection	Coastal protection Mangrove restoration		Coastal protection

This conclusion regarding the scope and tenor of the submitted NAPA project papers is consistent with many of the other NAPA documents submitted to the UNFCCC in the time since the passage of Decision 28/CP.7.

c. Comparison with other NAPAs

A review of other NAPA documents submitted to the UNFCCC suggests that Senegal is not alone in focusing its attention on primary, natural resource based sectors of its economy. Nor is Senegal alone in its definition of fairly broad development programs for these sectors as its priority adaptation activities. The NAPA process as originally conceived would tend to force the outcome in this direction by focusing primarily on strongly natural resource based areas and promoting a national level process to arrive at a series of projects that could be described and submitted to the UNFCCC as potential projects.

4. Filling Gaps in the NAPA Process

In 2006, Senegal initiated activity on NCAP supported activity and made the decision, in keeping with the benchmark that the 'project has coordinated effectively with the NAPA process and other relevant on-going and/or planned initiatives', to formally expand its official NAPA submittal to include priority adaptation activities in non-primary sectors of the Senegalese economy. This represented a significant shift from the sectors targeted in the original NAPA submittal and could provide a template that other countries might be able to follow in expanding their own NAPAs in the future. Here it should be stated that the NAPA coordinating team organized during the initial NAPA process had suggested that the climate change vulnerabilities of key elements of the service sector should also be considered with an eye toward developing adaptation strategies. The NCAP team in Senegal was anxious to use the available resources to respond to this suggestion.

5. New Sectors

The specific elements of the service sector that were identified for closer analysis were the tourism sector and the transport infrastructure sector. Tourism was selected because of its current importance to the Senegalese economy and anticipated expansions contemplated as part of national economic forecasts. The transport infrastructure sector was selected not so much for its direct contribution to the Senegalese economy as for the support function that it provided the entire economy. While consideration of these sectors certainly moved the NAPA analysis beyond the primary production sectors evaluated in the first phase, the challenge was to remain faithful to both the NAPA guidelines, which state that priority adaptation activities should contribute towards poverty reduction, and the NCAP objectives, which also makes specific mention of activities that contribute towards implementing national poverty reduction strategies.

a. Tourism

The tourism sector, which contributes 4.6% of Senegal's GDP is the second leading foreign exchange generator in the country. Over 20,000 international visitors per year come to Senegal, primarily to spend time on the coast that offers many magnificent beaches and many unique and interesting coastal ecosystems. The Senegalese government has identified tourism as a key sector in its recently developed Accelerated Growth Strategy because of the potential it has to create both revenue and employment. Current estimates are that over 100,000 people are employed as a result of the tourism sector, either directly in hotels and restaurants, or in allied occupations such as construction, land-based transport, artisan crafts, guiding, and market gardening. In addition to providing the government with valuable foreign exchange, salaries earned by those working in the tourism industry are a vital part of many family budgets. In 2003, the estimate was that the tourism industry in Senegal generated revenues of approximately $600 million.

This is clearly not a sector that can be ignored. While it is perhaps one step removed from the natural resource based livelihood strategies pursued by the rural poor who live below the poverty line, it offers a real potential for individuals, particularly young people who can perfect a European language, to move out of vulnerable agricultural livelihoods. It seems logical then that Senegal would target an expanded phase of it NAPA activity on this sector.

i. Identifying Vulnerable Areas

Senegal would very much like to develop its tourism industry outside of the coastal zone. One area of particular interest is the southeast, a region blessed with unique and interesting biodiversity and archeological feature, where higher elevations on the flanks of the Guinean Fouta Djallon Highland contribute to cooler temperatures. It is in this zone that early investment in eco-tourism is occurring. Nonetheless, for the immediate future the Senegalese tourism sector is focused on the narrow band along its expansive Atlantic Coast. Three areas in particular are the focus of current activity and incoming investment. These are the Sine-Saloume Delta, the Petite Cote and the Langue de Barbarie (see map on the right). The primary climate change vulnerabilities in these areas are related to sea level rise and accelerated coastal erosion. Particularly in the Sine-Saloum Delta and along the Petite Cote, mangrove forests where once protected coastal areas are in decline. In all three zones, beaches are eroding and the seafront retreating. Taken together these changes are contributing to dramatic changes in the coastal morphology, such as the breach of an important barrier peninsula at the mouth of a Sine-Saloum Delta shown in figure 4 both before (a) and after (b) the rupture.

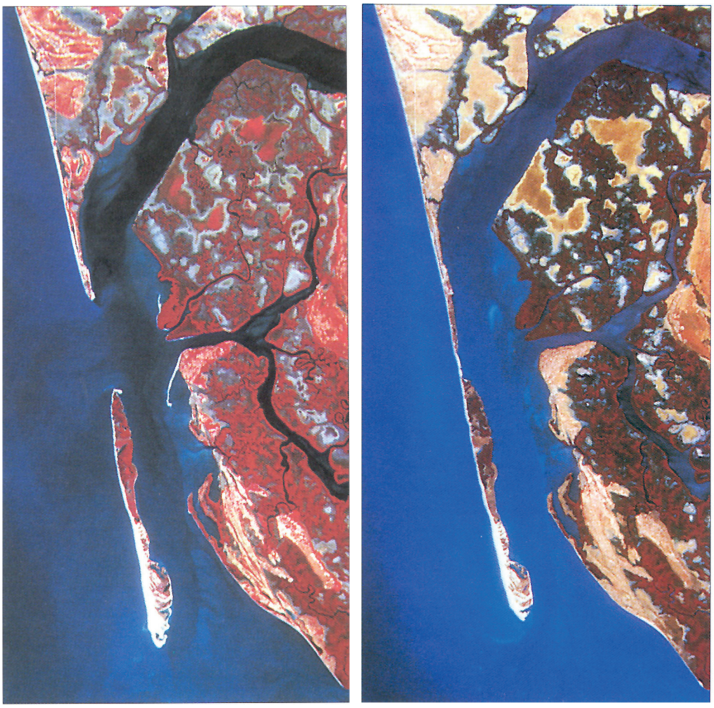

Figure 4: Dramatic Change along the Senegalese Coast Before and After (left to right)

Obviously these dramatic changes pose a real threat to the tourist accommodation that tends to be located extremely close to the seafront in Senegal, and will compromise the beachfront aesthetic that most tourists seek in traveling to Senegal. As part of the NAPA process supported by the NCAP project, an effort was made to characterize all of the possible climate change vulnerabilities posed to the tourism sector in these three locations. These are listed in table 3. The risk to the Senegalese tourist industry is that the combined impact of these threats, which would include compromised properties, narrow beaches, limited drinking water supplies, poor bio-diversity and natural attraction and generally uncomfortable temperatures, could make Senegal increasingly unattractive to tourists seeking a coastal holiday. This could have a devastating impact on this important sector the Senegalese economy.

Table 3: Climate Related Threats to Important Senegalese Tourist Zones

Sine-Saloum Delta	Petite Cote	Langue de Barbarie
• Saline intrusion into important fresh water supplies • Loss of biodiversity • Seafront erosion • Soil degradation • Elevated temperatures	• Seafront erosion • Loss of biodiversity • Land subsidence • Loss of beaches • Elevated temperatures	• Loss of bird life • Loss of beaches • Lose of endemic plant forms • Saline intrusion into important fresh water supplies • Seafront erosion • Elevated temperatures

Based on this assessment of vulnerabilities, public consultations were held with key players in the tourism sector in the target region to prioritize responsive adaptation activities.

ii. Defining Adaptations

In keeping with the NAPA process, consultants hired as part of the NCAP project developed a preliminary list of adaptation activities that could be presented during the public consultation process. These fell broadly into three categories. The first related to adaptations related to the management of the coastal zone itself. The second outlined adaptation strategies that could be applied to construction in the coastal zone that occurs to support the tourism sector. The final set of adaptations related to the structure of the sector itself. These are presented in the following lists.

Coastal zone management adaptation strategies proposed for consideration were classed according to a 'protect, adapt, or retreat' topology. These were:

- Construct coastal protection works, paying attention to the fact that these can degrade the natural beauty of the coastal environment;
- Restore natural protection such as mangroves or barrier islands;
- Construct new tourist accommodation and services farther from the seafront; and
- Importation of sand to eroded beaches, which is a temporary solution and can damage the zone from which sand is collected.

In terms of the adaptation strategies appropriate for the construction of buildings to support the tourism sector, the following potential adaptations were proposed:

- Replace concrete based construction, with high aggregate demands typically met by mining local beaches and dunes, with more traditional building materials;
- Construct all new buildings farther from the seafront;
- Require that the financial instruments used to secure construction funds of new construction directly on the seafront must mature over a shorter time frame consistent with the threat posed by coastal zone erosion; and
- Increase insurance premiums on new construction positioned directly on the seafront and ensure they mature over a shorter time frame consistent with the threat posed by coastal zone erosion.

In terms of proposed adaptation activities in the tourism sector itself, the following concepts were provided for public consultation:

- Develop new marketing strategies to increase interest in new tourism products offered in the interior of the country;

- Create an inter-ministerial panel to resolve problems confronting the tourism sector in the areas of health, water supply, and public works; and
- Encourage direct investment by players in the tourism sector in the protection of critical coastal zone ecosystems which are a central part of the tourist experience in Senegal.

It is interesting to note that these adaptations have a more targeted character than the more general development adaptations proposed for the agriculture, water resource, and coastal zone sectors in the first NAPA submission. The reasons for this difference and its implication for developing an adaptation plan of action are explored later in the paper.

iii. Defining projects

At the end of the public consultation process with key players in the tourism industry, a set of general policy adaptations were prioritized, along with specific actions to be taken in the three target zones. Policy adaptations were:

- Define a zone of maritime public domain, within which new construction and aggregate mining will be strictly prohibited;
- Require the preparation of Environmental Impact Reports for all new construction in the coastal zone; and
- Promote eco-tourism, particularly targeted at interior regions of the country.

Physical adaptation activities that emerged with priorities from the consultation process included the following actions:

- *Petite Cote:* Jetties constructed perpendicular to critical beaches to discourage further erosion and promote new beach deposition.
- *Sine-Saloum Delta:* Initiation of a mangrove rehabilitation project.
- *Sine-Saloum Delta and Langue de Barbarie:* Rainwater harvesting and solar brackish water desalination projects to relieve stress on potable water supplies associated with the tourism sector.

It is interesting to note here that the public consultation process generated priority adaptation activities that were even more targeted and specific than those elaborated by the NCAP team working on the NAPA supplement.

b. Transport Infrastructure

The established road network and transport fleet in Senegal plays a critical role in supporting the Senegalese economy. Estimates are that 10% of the country's GDP is generated via the road based transport of people and goods. This is not surprising given that 90% of internal displacements and 90% of shipped merchandise are moved by road in Senegal. Rail and air transportation and shipping links either do not service large areas of the country or are cost prohibitive to large portions of the population. The level of development of the transport infrastructure, shown in figure 5, is a critical factor in the efficient functioning of the diverse components of the national economy. Transport infrastructure is both itself an important economic sector and a critical element in most others. Primary production activities such as agriculture, fishing, and wood products are particularly dependent on the network for moving the goods produced in rural areas to distant markets.

A survey of traffic patterns conducted in 1996 provides a good picture of the structure of the Senegalese transport infrastructure sector. For private vehicles the primary zones of traffic emission are Dakar, Thiès, Kaolack and Diourbel. For commercial vehicles the primary zones of traffic emission are Dakar, Thiès, Kaolack and Saint Louis. Since the time of that survey, the number of trips has grown at an average national rate of over 1% per year, although traffic along roads in the western region of the country has grown at over twice that rate. Clearly the reliance on this road network is growing, primarily in the zone where the system itself is most threatened by potentially negative impacts of climate change, including sea level rise, floodplain inundation at the mouths of flooded rivers and temperature rise in this more temperate coastal region of the country.

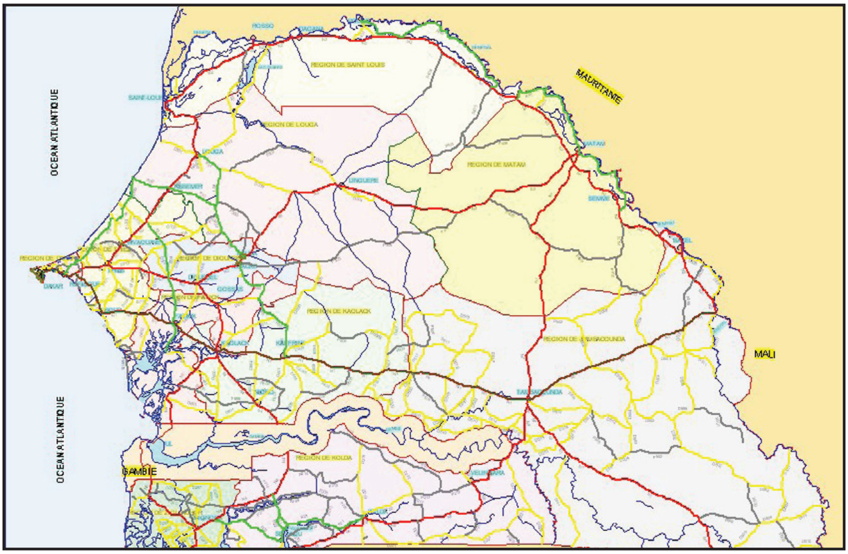

Figure 5: The Senegalese Road Network (primary Routes Nationales in red)

i. Identifying Vulnerable Areas

Climate scenarios suggest that in the future Senegal will be warmer and may experience increases in the intensity of storm events, particularly in the northern portion of the country. In this context the current state of the road network in Senegal is concerning, particularly when combined with the anticipated rise in sea level.

Currently the end of each rainy season is witness to the progressive decline in the quality of the road network as evident in the number of pot holes, cracks, and ruts which are exacerbated by later use. With a lack of maintenance these disruptions to the road surface can begin to degrade the road bed as well. It is also observed that poorly placed and sized roadway drainage systems can lead to the actual splitting of road surfaces during storms. The quality of paving materials, which is often sub-standard, can also leave roads susceptible to degradation during time of high temperature. Full flooding of roads is also a common phenomenon in low lying and coastal areas during the rainy season.

In terms of flooding two particularly vulnerable areas are the link between Saint-Louis and Bakel along the Senegal River where shifting sand disrupts the ability to install and manage a functional drainage system, leading to regular flooding and occasional road damage during storm events. In the Dakar region low lying roads are regularly damaged when heavy rains coincide with high tides and strong storm surges. Of particular concern is Route National 1 that links the capital to the rest of the country as an exit from the Cap Vert Peninsula and the Western Cornish Road that runs along the Atlantic seafront. Roads in the city of Saint-Louis itself are also prone to flooding when the Senegal River floods, the tides are high and the storm surges are strong. In light of the importance of these two urban centers, there are large efforts to define adaptation activities focused on these regions.

ii. Defining Adaptations

Based on the assessment of the vulnerability of the road network linked to potential changes in climate, combined with consideration of where disruptions to roads would have the largest negative impact on the national transport infrastructure system, a series of potential adaptation activities were developed in preparation for public consultation with key players in the sector. These included:

- The construction of new roadways around flood prone areas;
- The construction of suspended roads;
- Improvements to road drainage systems;
- Improvements in the quality of asphalt used to pave roads;
- The establishment of a regular road maintenance program to be implemented following each rainy season;
- Consolidation and reinforcement of road beds on seafront roads;
- The construction of seawalls and coastal zone protection measures; and
- A land use policy to shift population centers out of flood prone areas.

These adaptation activities were presented to key actors in the sector who then followed standard NAPA project prioritization methods to identify priority actions for which project papers were prepared and submitted to the UNFCCC.

iii. Defining Projects

At the end of the public consultation process the following adaptation activities emerged as priorities in order of their rank. The following activities were deemed appropriate in both the case of Dakar and the case of Saint-Louis:

- Regular roadway maintenance after each rainy season;
- Improvements to road drainage systems;
- Construction of new roads around flood prone areas;
- Improvement in the quality of asphalt; and
- Consolidation and reinforcement of road beds on seafront roads.

As in the case of priority adaptation actions for the tourism sector, those actions identified for the transport infrastructure sector have a more targeted character than the more general development adaptations proposed for the agriculture, water resource, and coastal zone sectors in the first NAPA submission.

6. Lessons for Other Overlooked Sectors

The example of work carried out in Senegal under the NCAP project to expand the country's NAPA submissions beyond the initial primary sectors of agriculture, water resources and coast zone management raises both some interesting questions and highlights some potential advantages of such effort. It is perhaps easier to begin with the potential advantages.

Firstly, as opposed to efforts to develop priority adaptation activities in the primary production sectors, which tend to occur to subsistence levels across wide areas of a country such as Senegal, components of the service sector, such as tourism, tend to be concentrated in more limited geographic areas. In the case of Senegal, it was possible for a national level consultative process to identify three critical zones of the tourism sector that were also vulnerable to climate change risk. Based on this calculation the Sine-Saloum Delta, the Petite Cote and the Langue de Barbarie quickly became the focus of analysis. Once this geographic focus was made, it was possible to develop more specific adaptation measures than can be the case when attempting to define adaptation activities for the entire agriculture sector in Senegal. This appears to be the case even when the country is divided into four regions as was done in the initial NAPA submission from Senegal.

It was perhaps even easier to focus the analysis dealing with transport infrastructure. Here the data suggested that the largest concentration of commercially related road traffic, vital to the efficient functioning of the overall economy, was in the regions around Dakar and Saint-Louis. That the roads in these areas are already experiencing problems linked to climatic phenomenon served to further motivate the choice to focus on these zones. As clear problems already exist, problems that can plausibly be assumed to become exacerbated under future climate change; it is relatively straight forward to define adaptation activities. The challenge comes in the development of the prioritized ranking.

Having identified priority adaptation activities for economic activity taking place outside the primary production sectors, it also seems easier to imagine implementing them should funding become available, over a distributed program to promote reforestation or rainwater harvesting across widely distributed communities and production zones. One can even imagine how to calculate the economic benefit of such adaptation activities using fairly standard analytical techniques. For example, estimates of the reduction in the number of days a road is closed thanks to an adaptation activity, use available statistics to sum up the number of trips that would have otherwise not been possible and multiply by some factor representing the value of the goods being transported.

Nonetheless, the greater ease with which a NAPA plan might be developed and implemented in a non-primary production sector does not change the fact that the NAPA program, and the NCAP project which supported the expansion of the NAPA process in Senegal, clearly focus on adaptations that can increase the adaptive capacity of poor people to withstand the negative impacts of climate change. It is here that the questions arise.

- Is it possible to justify climate change adaptation activities in non-primary production sectors by assuming that there will be a trickle down improvement for the poorest and most vulnerable members of society?
- Will the development of a submission to the UNFCCC of more concrete NAPA adaptation activities for non-primary production sectors disadvantage activities developed for the primary production sector when it comes to funding?
- Conversely, will investment in NAPA adaptation activities targeted at primary production sectors disadvantage activities designed for service sectors that could eventually create opportunities for people to move out of what are likely to be increasingly vulnerable primary production sectors under future climate regimes?

These are hard questions and NCAP activity in Senegal has brought them to the forefront. While this paper is not in a position to take them on directly, they do suggest some thoughts on useful recommendations for other countries that would like to expand their own NAPA submittals to the UNFCCC beyond their own primary production sectors.

7. Recommendations and Conclusions

The most helpful realization for grappling with the vexing questions seems to be that as of yet no funding mechanism is in place to implement the long lists of priority adaptation activities that have be filed with the UNFCCC as part of the NAPA process. While it appears that the climate change adaptation dialogue is gaining momentum and that it will be a central part of the Post-Kyoto negotiations scheduled for Copenhagen in 2009, there is still no stable funding mechanism for adaptation activities in the least developed countries.

In this context it seems prudent for countries to develop NAPA priority adaptation activities for non-primary production sectors as there is no way of knowing what project selection criteria will be applied. If the criteria favor discrete activities that can be completed in limited windows of time, it may be a good idea to have some road reconstruction projects on file along with the project to scale up community based rainwater harvesting technology to a regional or national scale. If the criteria require direct investment in the current activities of the poor, then a country will be pleased to have a national reforestation initiative on file along with a proposal to restore a beach in a critical tourist region. In the absence of clear guidance as to which sorts of projects will be funded from an eventual global adaptation fund, it makes sense to develop a wide range of projects.

More fundamentally, however, moving the NAPA process beyond the primary production sectors forces the issue of what sort of economy a country would like to develop out into the open, and challenges policy makers to assess which economy is the most resilient to climate change. This is a conversation that has no end, no point of definitive certainty. Instead it is a conversation that once engaged will facilitate and open a productive dialogue about how we are to confront humanity's central challenge for the 21st century. The NCAP team in Senegal should be commended for their efforts to initiate this conversation.

Promotion of Sustainable Livelihood within the Coastal Zone of Suriname, with Emphasis on Greater Paramaribo and Wanica

Sieuwnath Naipal and Adriaan Tas

Introduction

The Republic of Suriname, situated on the northeast coast of South America, occupies 163,265km^2 of which about 90% is covered with rainforest. It has a population of approximately 492,829 (August 2005) of which 97% is concentrated in the low-lying coastal zone, and especially in and around the capital city of Paramaribo (about 70%). The remaining 3% of Suriname's population is spread over small and tribal communities along rivers. The average population density of 2.9 people/km^2 indicates that Suriname is very sparsely populated. This average stands in stark contrast to the population densities of Paramaribo and Wanica, the two most important coastal districts of the country, of 1,327.6 people/km^2 and 194.1 people/km^2 respectively.

The climate is semi-humid, characterized by two rainy seasons and two dry seasons. The short rainy season takes place between December and February with a mean monthly rainfall of about 200mm. The short rainy season is followed by a short dry season (February to April) with a mean monthly rainfall of about 100mm. The long rainy season starts in May and ends around the middle of August reaching mean monthly rainfall averages of around 200mm with a maximum of 325mm during the wettest month. The long dry season has a mean monthly rainfall of less than 100mm and takes place from the middle of August to December. Total rainfall is the highest during the long wet season (May to August) and provides 50 to 70% of the total annual rainfall, whilst the contribution of the short wet season is about 17 to 25% of the total. Besides the high rainfall, high evaporation rates (±1,400mm/year) are also observed.

In the coastal zone complex mangrove ecosystems are home to many types of fish, marine invertebrates, sea turtles and huge numbers of migratory birds creating a high biological diversity. The region is also considered as the principal South American wintering ground for shore birds of borealic and Arctic regions.

The economy of Suriname is dominated mainly by bauxite and petroleum industries, the former accounting for more than 15% of GDP and 70% of export earnings. Other important economic activities include services, gold mining, agriculture (rice, banana and vegetable production), logging, food processing, cattle farming and fishing, and more recently tourism. The Government of Suriname is one of the largest employers, providing work for almost 40,000 civil servants. More than 90% of the economic activities are located in the coastal zone especially in the Paramaribo and Wanica districts. Taken together, these activities account for more than 80% of the country's GDP. This indicates the huge importance these coastal areas hold for Suriname's economy as a whole. The effects of global warming and accelerated sea level rise are therefore considered to be a serious threat for the sustainable development of the country.

Background and Rationale

Studies dealing with climate change and its impacts on the various sectors in Suriname started seriously with the implementation of the first Netherlands Climate Change Studies and Assistance Program (NCCSAP-I). Studies carried out under this first phase convincingly showed that the impacts of sea level rise on Suriname can be significant and the project identified Paramaribo and Wanica as the most vulnerable districts in terms of economic losses and impacts on the population. The study also concluded that 'Suriname ranks with the small island states as being among the most vulnerable nations in the world to the impacts of accelerated sea level rise'. This conclusion was reaffirmed in a more recent study carried out by the World Bank, which assessed the consequences of continued sea level rise for 84 developing countries and listed Suriname as one of the 10 most vulnerable countries in terms of impacts on GDP, agriculture, population and urban areas. Apart from sea level rise, it has also been noted that climate change will result in increased climate variability in Suriname, causing abundant rainfall in shorter periods of time as well as prolonged droughts. Both extremes of the hydrological cycle are expected to further add to the negative impacts of climate change in Suriname.

In response to these observations, various studies and reports have proposed and formulated adaptation measures for coping with the adverse impacts of climate. Most of the proposed measures, however, are of a rather generic nature and a need to tailor them to the local contexts still exists. More specifically, the need to elaborate a specific set of adaptation measures for the two most vulnerable districts, Paramaribo and Wanica has been identified.

The project 'Promotion of Sustainable Livelihood Within the Coastal Zone of Suriname, with Emphasis on Paramaribo and the Immediate Region', which was implemented under the second phase of the Netherlands Climate Assistance Program (NCAP-II), has sought to respond to this need and has worked on the elaboration of a more detailed and specific adaptation strategy for Paramaribo and Wanica. The development of the adaptation strategy included an assessment and evaluation of the feasibility of the proposed measures, a specification of the financial needs for implementing the proposed measures and the identification of potential (international) financial resources. In addition, the project sought to:

- Develop a more detailed picture of the vulnerabilities of the different sectors in Paramaribo and Wanica;
- Contribute towards the formulation of a national climate change policy; and
- Further raise awareness of the issue of climate change among policy makers and the general public.

The project took place from May 2005 to June 2008. The overall project management in Suriname was in the hands of The Ministry of Labor, Technological Development and Environment (ATM). The Anton de Kom University, in collaboration with local consultants and experts, was responsible for the day-to-day implementation of the project. A Climate Change Steering Committee (CCSC), consisting of members of various ministries and departments, was established to oversee and monitor the project.

The Study Area and Methodological Approach

The study area included the capital of the country, Paramaribo, and the neighboring district Wanica. This area borders in the east with the Suriname River, in the west with the district of Saramacca, in the north with the Atlantic Ocean, and in the south with the district of Para.

In general the study area can be characterized as an area comprising few natural resources, extensive manmade structures and human settlements, with relative high population concentration, the majority living and working in the immediate region of Paramaribo. The total coastal length of Paramaribo and Wanica is about 20km, representing about 5.2% of the total coastline of Suriname. Paramaribo and Wanica belong to the administrative, political and cultural center of Suriname. The presence of the Saramacca Canal, connecting the Suriname River and the Saramacca River, creates unique possibilities for the irrigation, drainage, water transportation and opportunities for industrial growth in the central part of the study region. The northern part of the Saramacca Canal, the area between the Kwatta Ridge and the coastline, is relatively lower than the southern part of the canal in the direction of Lelydorp. Conversely, the northern part, in particular the area of Weg naar Zee, is more fertile than areas south of the canal, therefore determining the type of agricultural practices in these areas. The study area is currently undergoing rapid growth in terms of human settlements and establishment of infrastructures and other facilities.

In order to develop and formulate specific adaptation measures for Paramaribo and Wanica, the study started with a detailed description and updating of the present conditions in the study area in terms of geology, ecology, water resources, agriculture, socio-economics and human health. The description of this present profile helped in understanding the baseline vulnerabilities in the study area.

Taking the present profile as a starting point, scenarios were developed describing possible future conditions in the different sectors. The methodology used to describe the future profile was largely based on a detailed study of the available literature, intensive discussions and consultations with stakeholders and professionals, consultation of multi annual plans of the Government, other policy documents and findings of workshops. Local site visits and discussions with the local communities and other relevant stakeholders living and working in the vulnerable area further helped in determining future projections of the different sectors. In terms of future climate conditions, the following data and information was used for the elaboration of the future profiles:

- Temperature increase of 2 to 3°C by the year 2100 based on the projections of the IPCC Fourth Assessment Report.
- Changes in the precipitation pattern. Increased variability in rainfall and drought are projected for the future. The strong rainfall events in May and June of 2006 in the interior of the country, as well as the rainfall events in May 2007 in the capital Paramaribo are expected to become more frequent in the future. These changes may also lead to disruption of the hydrological cycle of the particular region or basin.
- A relative sea level rise of 1m is used for determining the future profile of the sectors. This value comprises the following parameters;
    - The sea level rise as projected by the IPCC (approximately 30 to 80cm in the coming 100 years);
    - Subsidence of 20 to 40cm, due to human activities in the coastal zone, e.g. empoldering of the low-lying coastal areas;
    - Storm surges of 20 to 30cm, fostered also by the change in the wind velocity and wind direction; and
    - Backwater effects and other anomalies of approximately 10cm.

In a final step, and based on the detailed descriptions of the present and future profiles, the study team developed and formulated a specific set of adaptation measures for Paramaribo and Wanica. Two types of adaptations measures were considered:

1. Adaptation measures that are part of common government policy and actions; and
2. Adaptation measures that constitute a specific response to the increased threat of climate related hazards (with a focus on accelerated sea level rise).

Various meetings and workshops were organized to present and discuss the proposed measures with stakeholders and policymakers. The meetings and workshops also provided an opportunity

to further elaborate the adaptation measures and assess their feasibility and acceptance among different stakeholders. Feedback from the CCSC and others were made also useful in this process of elaboration adaptation measures.
Results

Impact Studies and Scenario Development

Geomorphology

The study area is located in the coastal plain of Suriname, which is predominantly formed on marine deposits. This coastal plain comprises two distinct parts, the Old Coastal Plain, which was formed during the Pleistocene era, and the Young Coastal Plain, which is of Holocene age. The Young Coastal Plain covers the major part of the study area. It has a width of about 20km and it covers an area of over 500km^2 (approximately 85% of the project area).

Within Suriname the Young Coastal Plain features extensive, flat and low-lying areas of heavy marine clays usually overlain by a layer of peat (locally known as *pegasse*). The clay flats have a very low elevation with the major part having elevations of between 0.5 and 1.5m above mean sea level. If not artificially drained, these areas are flooded in the rainy seasons, and often also part of the dry seasons, forming swamps. Apart from its elevation, the water depth in these swamps will also depend upon other local conditions, like distance from the river or sea and the drainage opportunities along the swamp edges.

The clay flats are locally interspersed by roughly east–west striking ridges. The ridges form elongated, usually narrow bodies, often consisting of sand, but sometimes a mixture of broken and whole shells. The ridges, that rise 1 to 3m above the surrounding clay flats, may be either individual or occur in groups and they may be between 20 and 400m wide. Ridge groups are particularly abundant to the west of the main rivers.

A cross section through the northern study area is presented in figure 1.

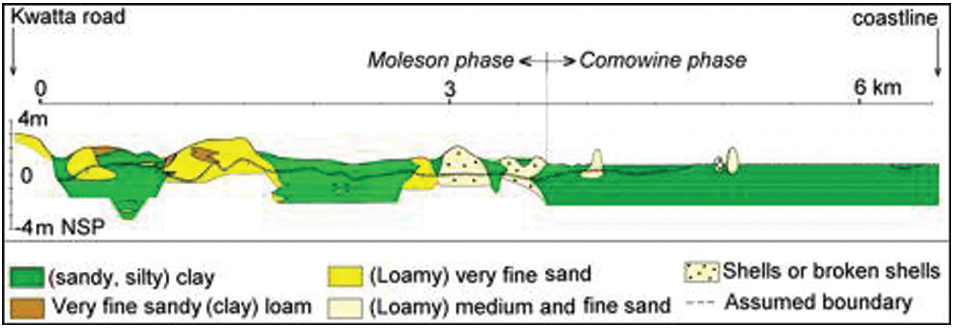

Figure 1: Cross Section through the Northern Part of the Study Area

The Suriname coast is subjected to an active geomorphological development, which is determined by a system of cyclic accretion and erosion. Both are linked to the presence of mudflats/ mudbanks[1], which continuously migrate to the west driven by the alongshore Guiana Current and wave action. Based on several investigations and historical information, an average mudbank has

1 Mudbanks have been defined as the sub-tidal extension of the intertidal mudflats; below the term mudbank will be used for the whole mudflat/mudbank

a length of 45km and a life cycle of approximately 30 years. Recent investigations indicate that certain mechanisms modify this general pattern. Cyclic changes in wind direction and wind speed (and connected with that, the wave climate) are thought to result in (cyclic) changes in mudbank characteristics and changes in the coastal erosion and accretion cycle. A very long mudbank is currently found east of Braamspunt. This mudbank of 70km in length will reach the mouth of the Suriname River within about 20 to 30 years. It is expected that Braamspunt will then develop as a "mudscape" pushing the mouth of the Suriname River towards the west. When this happens it will have considerable consequences for the navigation of the Suriname River. Accretion and erosion are characterized by specific landscapes, which often succeed each other within one accretion-erosion cycle. Three major types of coastal landscapes have been distinguished along the Suriname coast, a mud accretionary coast, a sand accretionary coast and an erosional coast.

In several locations, soil dams have been put up to stop erosion and penetration of seawater. The Ministry of Public Works has frequently executed maintenance works on the soil dam at Weg naar Zee to prevent inundation, land degradation and further land loss. However, these works last for only a few years. In the absence of some natural barriers and manmade infrastructure, it is expected that large parts of the northern coast will be inundated and ground as well as surface water resources will be deteriorated due to sea level rise and changes in precipitation. Being aware of these potential impacts, the Ministry of Public Works has started the explore options for building an enclosed dike aiming to protect the northern coastal area against flooding from the swamp and seawater, and establishing a ring canal for the drainage of excess water. A buffer zone of about 0.5 to 4.0km (measurements yet to be decided) between the coastline and the enclosed dike is taken into account, including the expected impacts of this dike on the estuarine zone and those of the sea level rise in the future.

Ecology

The study area is dominated by manmade and man-affected ecosystems with residential and agricultural areas covering most of it. Significant areas with remaining natural or semi-natural ecosystems are found at three isolated locations within the study area. The two northern areas comprise coastal wetlands with mangrove forests, brackish water swamps and related freshwater swamps, as well as some indistinct areas with ridge forest. In the southern direction the swamp waters may become fresh and linked with a freshwater riverine swamp area, with recent and old (high) clay levees and backswamps. These (semi-) natural areas cover only 13% of the study area. In other districts of Suriname (semi-) natural ecosystems are much more common.

The coastal ecosystems have multiple values and functions, including coastal protection, natural productivity, biodiversity and carbon storage. Especially, the coastal protection function of the mangrove forest is clearly demonstrated in the study area where erosion is much more severe along unprotected stretches of the coast than along forested sections.

Despite the multiple values and functions of the coastal ecosystems, considerable areas have been turned into agricultural, residential and aquacultural land. In the absence of land use planning, as is still the case in Suriname, many such developments take place more or less randomly. This process is expected to continue over the coming years. In the long run, however, this trend might be reversed due to climate change induced flooding and salinity intrusion, which will force people to abandon the most vulnerable areas close to the ocean. In these areas, the natural ecosystem will gradually regenerate. The mudflat, which will reach the Paramaribo-Wanica coast in the next 20 to 30 years, might also contribute to the reestablishment of the Black Mangrove forest. South of this mangrove zone, saline and brackish ecosystems will show a considerable extension towards the south, into the current freshwater swamps. Extensive lagoons will form in the brackish to saline zone. The creation of open water will result in an increase in wildlife, especially birds and fish.

On the other hand, climate change and sea level rise are also expected to negatively affect the wetland ecosystems in the coastal plain, because changes in the drainage basins and the tidal regime will affect the hydrology of these low lying and flat areas. Changes in water quality (salinity) will also cause considerable changes in the sea-bound coastal wetlands. Indirectly the hydrology may also affect the occurrence of vegetation and peat fires, another important factor that determines the vegetation status in the Young Coastal Plain. To a lesser degree, changes in the rainfall pattern and temperature in the coastal plain may have an impact on the wetland ecosystems. Changes in temperature and CO2 levels will certainly affect all ecosystems in Suriname, but their impact cannot yet be predicted.

Given the above, it can be concluded that many different processes are affecting the ecosystem conditions in the project area. The effects of climate change are expected to be both positive and negative.

Water

Suriname is one of the top 10 water-rich countries of the world. The renewable annual fresh water available in Suriname is estimated at 473,934 m^3/capita. Despite this abundance, water availability may periodically suffer problems especially during dry seasons and years affected by strong "El Niño" events. The surface freshwater resources consist of the Suriname River in the east and the Saramacca River in the west. Groundwater in the study area can be divided into shallow (0.5 to 5m) and deep (>5m) groundwater resources. In northern parts the shallow groundwater is saline whilst in the southern part this is fresh. The deep groundwater may be fresh in the coastal zone. The different aquifers, such as the Zanderij (average depth of 30 to 50m), A-zand (at a depth of 120 to 160m) and the Coesewijne (230m), are the important freshwater aquifers in the study area.

Water in the study area is mainly utilized at domestic and industrial levels, for agricultural purposes (irrigation and cattle watering) and fire control. No special management system exists for regulating and ensuring the provision of freshwater for maintaining ecosystems or facilitating navigation or fisheries.

Water for domestic purposes is supplied by two governmental water supply agencies, the Surinamese Water Supply Company (SWM) and the Service for Water Supply (DWV). The SWM is the largest water supplier, providing water to 93.7% of the households in Paramaribo and 74.5% of the households in Wanica. For this, the SWM withdraws approximately 90,000m^3 water/day from the existing aquifers in the coastal plain through ten production wells. About 52% of the produced water is delivered as metered water. The remaining is not metered and can be considered as wasted due to, among other reasons, operations and leakages. In rural areas, the provision of drinking water largely depends on rainfall and shallow groundwater occurrences. As population increases in these areas water supply companies do expand their infrastructure. The Government of Suriname aims to connect 95% of the population in the urban area to the water network. The target for rural areas is set at 70% of the population.

Except for domestic purposes water is also used for purposes such as the production of beer, bottling of water, and use for other beverages. Other industrial processes include the metal industry and fabrication of natural stone products.

As agricultural activities are relatively well developed in the district of Wanica, a significant amount of freshwater is required for agricultural purposes. Large parts of the agricultural areas are not irrigated but depend on rainwater, available soil moisture and local surface water. Therefore, a lack of rain in the dry seasons seriously affects the agriculture and the livelihood of the farmers, in particular in the northern located horticultural areas. Water for the banana and rice farms on the western border is obtained from the Saramacca River, which is well stocked.

Apart from water requirements for socio-economic needs, freshwater is also needed for maintaining the natural ecosystems, including the mangrove ecosystems in the north, on the coastline and by the estuary of the Suriname River. When the aquatic conditions do not meet the required conditions, mangrove vegetation may not develop whilst the existing mangrove forest may degrade. To meet the required conditions, appropriate mixing of freshwater supplied from inland with the brackish seawater is needed.

Water quality in the study area is subjected to pollution from agricultural, industrial, mining and domestic sources. Under natural conditions, pollution also occurs through penetration of salt water into freshwater resources, particular during the dry seasons. Domestic wastewater is drained through the sewer systems into the rivers and open swamps. The area needs a central sewer treatment plant. There are also no regulations for draining industrial wastewater. During heavy and consistent rainfall excess water may flush pollutants over large areas, including waste from septic tanks. In addition many septic tanks don't always function properly due to incorrect construction or leakage. Studies have shown significant pollution of groundwater in the immediate area of the septic tanks. The agro-chemicals and fertilizers used in the agricultural sector are flushed out by rain and irrigation water and transported by the drainage system into the natural water systems. In the small-scale agricultural sector this is of minor concern. However in areas where relatively large-scale agricultural activities are taking place, i.e. near the western border of the study area (banana and rice sector), the threat may be significant.

The drainage system in the study area is based on polder water management structures. There are in total 35 drainage areas within Paramaribo, comprising open and close conduits. Each drainage area is an independent unit drained by means of sluices and/or pumping stations. Currently, the Ministry of Public Works is constructing new pumping stations at several locations in the study area to improve the drainage capacity. However, inadequate maintenance of the existing drainage systems results in frequent flooding of the urban areas during the rainy seasons. About 13% of the urban area and 13,000 inhabitants are directly affected. Necessary steps and great efforts have been taken to improve the drainage conditions in the past years.

It is expected that climate change will have many negative impacts on the water resources in Suriname, both in terms of quality and quantity. If no measures are taken, large parts of the study area will be inundated and tidal waters will intrude deep into the natural area. In combination with increased evapotranspiration this may lead to increased salinization. Intensive rainfall events will put increasing pressure on the drainage systems causing further pollution from excess wastewater from industries, agriculture and households. Prolonged droughts, in turn, will cause severe water shortages, which will negatively affect many of the key sectors in Suriname, including agriculture, energy and industries.

Agriculture

The total area suitable for agriculture in Suriname accounts for about 1.5 million ha of land, but only 120,000ha of agricultural land is presently under cultivation. About 85% of the land suitable for agriculture lies in the coastal area and the other 15% is situated in the interior as river terraces. The fertile soil of the young coastal plain and the large freshwater swamps and rivers in the north have together created ideal conditions for developing large-scale agriculture. Relatively large-scale rice and banana production are found in the coastal plain, which is for the greater part concentrated in the western districts.

Agriculture in the study area is largely concentrated on horticulture, fisheries and livestock production. Most of these activities are located in the Wanica district. Based on these activities the Wanica district is divided into 3 production units: Wanica A (including areas north of the Saramacca Canal); Wanica B (including the resorts of Domburg and Houttuin); and Wanica C (including the resorts of Nieuwe Grond, Koewarasan and Lelydorp).

In general, crops are harvested on small farms (0.6 to 6.0 ha) where only part of the land is used for crop production. The traditional areas for vegetable and fruit production, such as Pomona, Weg naar Zee, Uitkijk-Leidingen, Santo Boma, Koewarasan and Houttuin, show a negative trend in terms of production. New horticultural production areas have been started in the recent years in the districts of Saramacca, Comowine and Para. A shift is taking place in what is produced on these farms. As well as the primary production of vegetables, most of the farmers produce fruit (citrus fruits, bananas, mangos and papayas) on a small scale since land is a major limiting factor.

A typical small vegetable producing farm can be characterized as follows:

- land in production is in between 0.16 and 0.32ha;
- the farmer is a part-time farmer with other sources of income;
- part time labor is hired when necessary;
- farmers do not specialize in one specific crop;
- only land preparation is mechanized;
- in general farmers never received an education in agriculture, the knowledge they have is gained through practical experience;
- marketing of vegetables produced is through wholesale buyers and/or middle men;
- the risk of harvest failure is high;
- the main problems that farmers have to deal with are financial problems (high interest rates at commercial banks) and poor maintenance of drainage infrastructure.

Under present conditions of climate change and variability, over short time periods both flash flooding due to heavy rainfall and sustained drought may occur. Consequently, dependence on rainfall as a water resource for horticulture is not reliable. Therefore utilization of modern greenhouses based on drip irrigation and/or hydroponics is a prerequisite for higher yields. In Suriname however, the adaptation to these modern facilities for vegetable and/or horticultural production is evolving slowly.

The Wanica district is also the most important district for milk, poultry, small ruminant and pig production. More than one third (36.8%) of all the grassland is located in this district. These grasslands, even though they are located at higher altitude than the coastal plains, are often flooded during heavy rainfall, which negatively affects livestock production. Livestock productivity is also affected by the high ambient temperatures and humidity. This is what is currently affecting the dairy sector the most.

Within the dairy sector 400 farmers and transporters of milk are registered. More than 40% of milk sold comes from local farmers and provides support for food security, poverty alleviation, and income generation. Recently new dairy processing methods have been introduced using imported milk powder for producing cheap dairy products. In addition, the resilience of the dairy sector is limited by the lack of necessary infrastructure such as irrigation and drainage systems for existing grasslands, the low number of farmers, small pasture lands, and no adequate administration.

On the more poorly drained clay land of the Young Coastal Plain extensive or semi-extensive farming systems for production of beef cattle are found. These types of cattle are well adapted to high temperatures and therefore fewer thermoregulation problems with beef production are experienced. Farmers of beef cattle are often only part-time. In comparison, dairy cattle require good housing and management, and are less adapted to the ambient temperature. Serious threats to beef cattle production are frequent due to flooding because of poor drainage systems. In the coastal area, threats may come from flooding due to dam breaches during high spring tides and the consequential saltwater intrusion on pastures close to the sea results in significant losses of grassland.

Poultry and pigs produced under small intensive farming systems are less affected by climate change impacts. Most of the farms (more than 70%) are concentrated in the southern part of Wanica. The main negative climatic impacts on poultry production come from the persistent high temperatures in the pens or coops during the long dry season. In this season the mortality rate of chickens increases significantly on farms with traditional housing systems. The expectation is that new modern farms with facilities for complete climate control will be constructed in the Lelydorp area and the Zanderij area. These modern farms will be better adapted to the problems of climate change.

In general however, food production and food processing in the study area already shows signs of decline. If no measures are taken, further decline will be observed and it is expected that this negative trend will be further enhanced by the adverse impacts of climate change, in particular in the northern areas. Ongoing urbanization will push the agriculture further south in the study area but also beyond its limit to other neighboring districts. There will also be a loss of fertile land due to flooding since higher elevated regions are relatively less suitable for agriculture.

It can be concluded that food production could be sustained under changing climatic conditions through the application of climate controlled techniques and mechanisms and the improvement of water management and irrigation systems. However, all these proposals require strong and aggressive promotion to substantially raise awareness. Other facilities such as those related to financial support, guidance of farmers at field level and training are of utmost important and highly recommended. Last but not least good spatial planning is required for this sector to guarantee the sustainability, good food provision and food security.

Health

The persistent increase of temperature, sea level rise and changes in precipitation are expected to affect human health in Suriname both directly and indirectly. Temperature rise may cause heat related mortality and morbidity and an increase in respiratory illnesses, whilst changes in precipitation could lead to an increase in mortality due to the frequency of floods, storms and other natural disasters. Sea level rise may also cause a loss of inhabitable land, contaminate fresh water supplies and inflict damage on public health facilities. As well as the above mentioned effects, health conditions could also be impacted by so-called ecosystem mediated health effects, which include changes in the distribution and seasonality of vector and waterborne diseases and an increase in growth of toxic algae and food shortages.

Despite these general observations, the specific impacts of global climate change on human health conditions in Paramaribo and Wanica are still largely unpredictable. Increased temperatures and sea levels, as well as alternating rainfall with severe droughts and floods, will have indirect effects on human health, which in general are negative for Suriname. Nevertheless, some adaptations can be made.

Malaria, which is endemic in parts of internal Suriname, does not occur in the coastal region. However, there are two potential vectors for malaria present on the coast, the *A. aquasalis* (most dominant) and *A. nuneztovari*. Since *A. aquasalis* is not an efficient vector for malaria in Suriname, it is not very likely that the occurrence of malaria will increase under future climate conditions.

Dengue, however, which is a viral disease characterized by an abrupt onset of high fever, headache, pain in the joints, myalgia, retro-orbital pain and rash, is endemic in Suriname. The warm and moist climates are favourable conditions for its development. Two serious complications of this disease have been observed; dengue hemorrhagic fever (DHF) and dengue shock syndrome (DSS). The most well known vector is the *A. aegypti*, a day-biter, which resides in manmade sites with suitable breeding environments, such as rainwater tanks, barrels and gutters of houses, amongst others. It is expected that future increases in short and heavy rainfall events will increase the number of available breeding sites for *A. aegypti* and as such contribute towards a wider distribution of dengue. The same is the case for yellow fever which is transmitted by the same mosquito.

Schistosomiasis or bilharzia is another endemic disease in Suriname. The occurrence of the disease is restricted to the coastal region, since the vector, the snail *Biomphalaria glabrata*, is only found in the region of coastal shell-ridges which are in the districts of Paramaribo, Wanica, Saramacca, Commewine and Coronie. The number of cases of bilharzia in Suriname decreased dramatically in the period 1975 to 1980 (from 26% to 5%) as a result of bilharzia control campaigns. Since 1980, the number of cases of bilharzia is stable (below 5%). The occurrence of bilharzia is expected to further decline in the context of climate change because the disease has less chance of survival in a saline environment.

Waterborne diseases, like shigellosis, typhoid fever, cholera and leptospirosis (Weil's disease) on the other hand, are expected to increase under conditions of severe rainfall and flood events. Shigellosis is caused by bacteria and is endemic in Suriname. The bacteria occur in the faeces of infected people, and contaminated food and water infect others indirectly. This disease, symptoms of which are diarrhoea, fever, vomiting, nausea, stomach pain and dysentery, may finally cause death in children if appropriate measures are not taken in time. At a national level, a significant number of cases varying between 90 and 120 were registered annually in the period 2000 to 2004. Typhoid fever is caused by the bacteria *Salmonella typhi* and is also endemic in Suriname. In the period 2000 to 2004, the total number of cases registered varied annually from 56 to 104. The disease has been predominantly observed in villages in internal Suriname. Cholera is caused by the bacteria *Vibrio cholerae* and is a particularly dangerous disease. Food and water contaminated with cholera-infected faeces can lead to cholera outbreaks. Leptospirosis (Weil's disease) is caused by bacteria of the order *spirochaetosis* and is present in the urine of infected rats. People may become infected with leptospirosis bacteria after having been in contact with infected water. Consequently, most leptospirosis cases occur in the long rainy season. Out of the 682 suspected cases registered in the period 2000 to 2003, of which 478 were tested in the laboratory, 90 were found positive.

Heat related mortality and morbidity is limited in Suriname. Even an increased air temperature is not likely to cause heat waves and therefore there would be low incidences of heat-related mortality. Information regarding the pollution-related respiratory disease baseline data is lacking and therefore it's difficult to predict the possible impacts.

Institutional Landscape and Land Use Planning for Coastal Zone Management: The Current Situation

The management of coastal districts of Suriname takes place at both the sector and district level. At the sector level, different ministries are responsible for implementing policies nationwide and promoting the interests of the sectors that they represent. Specifically the Ministry of Agriculture, Livestock and Fisheries; the Ministry of Natural Resources and Energy; the Ministry of Public Works; and the Ministry of Labor, Technological Development and Environment are closely involved with activities related to coastal zone management and the effects of climate change. The Ministry of Planning and Development Cooperation (PLOS) coordinates the planning activities of the government. The newly established Ministry of Spatial Planning, Land and Forest Management will soon play an important role in management of the coastal zone.

At the district level, the District Commissioner (DC), who falls under the remit of the Ministry of Regional Development, is the focal point, although other ministries maintain representation at the district level. The DC acts in close cooperation with the elected District Councils to marshal general management and the economic promotion and development of the district. A problem here is that the DC does not exercise financial independence and doesn't have his/her own budget.

Recently (2002 to 2005) the government has started a process of decentralization of diverse activities including financial decentralization. The Ministry of Regional Affairs is taking the lead in this process.

With the formation of the National Environment Council (NMR) in 1997 and the institutionalization of the National Institute for Environment and Development (NIMOS) in 1998, environmentally related activities are getting increasing attention. Since the establishment of NIMOS, much has been done in the way of enforcing relevant laws, awareness raising, strengthening institutional capacity and local expertise, and sourcing the required financial aid to enable the execution of many environmentally related activities, including coastal management.

Since the coastal zone will remain under great pressure from the ocean and its rising water levels, management of the coast will be of highest priority in the near future. As a result, the institute for Integrated Coastal Zone Management might become one of the most important institutes in the country. The ministries of Agriculture, Livestock and Fisheries; Natural Resources and Energy; and Public Works will be closely involved with activities related to coastal zone management and the effects of climate change.

The DCs will get more power to influence policy and activities in their districts. Changes in the election structure will also affect the development of the country. Notwithstanding these circumstances, the districts will be linked tightly with the capital city Paramaribo.

As well as the institutions like the NMR and NIMOS other environmentally related institutions will be established as more and more people become aware that the environment is of utmost importance to protect, otherwise disaster may be experienced sooner than later. Capacity at these institutions will increase as more will need to be done to implement relevant laws, raise awareness, and source the required financial resources.

Despite these institutional frameworks and developments, it has been realized that a lot needs to be done in order to enforce and implement a sound climate change adaptation policy in Suriname. In response to these concerns, the NCAP project in Suriname hosted a widely attended conference on 'Water and Future Development in Suriname'. One of the main points that emerged from the conference was the necessity to establish a Climate Change Coordination Commission, consisting of experts from different sectors of society, preferably cutting across the ministerial levels. The commission should be responsible for advising the government about measures for dealing with the direct and indirect consequences of climate change. The government would not take any decision in relation to climate change without first seeking the advice of the commission. The Ministry of Labor, Technology and Environment will take the initiative to establish the commission.

In terms of spatial planning, Suriname has already delineated 16 protected areas since 1966, covering approximately 13% of the land surface of Suriname. These protected areas comprise 11 Nature Reserves (NR's), 1 Nature Park (NP), and 4 Multiple-Use Management Areas (MUMAs).

As it was recognized that protection of a small part of the coast was not adequate to meet the overall goals, this concept of MUMAs was adopted. MUMAs are defined as areas where special management by or on behalf of the government is needed for the sustainable use of the natural resources, which includes the protection of vulnerable ecosystems and species. MUMAs have been established in most of the estuarine zone. The goals of these MUMAs are:

- To optimize their long-term productivity and sustainable use by man;
- To optimize the long term natural productivity of the estuarine land zone and the bordering ocean; and
- To promote the development of sustainable production processes in manmade ecosystems (such as agriculture, animal husbandry and oil exploitation), taking into consideration the demand of unspoiled ecosystem areas.

The only part of the Surinamese coast that is not included within the MUMA area is the Paramaribo-Wanica coastal zone, because here all land, including land in the mangrove zone, had already been issued to third parties. Land use in this zone has already led to serious degradation of the coastal wetlands and of its functions. In order to reverse these trends, urgent steps are needed to improve land use and spatial planning in the project area.

Adaptation Measures

The impact assessments and scenarios developed in the context of this project all confirm the findings and conclusions from previous studies that climate change will have serious impacts on the coastal zone and its sectors. In order to respond to these increasing threats, the project has developed an adaptation strategy for the most important districts of Paramaribo and Wanica. The proposed adaptation strategy consists of both adaptation measures that are part of common government policy and adaptation measures that constitute a specific response to the increased threat of climate change related hazards and impacts. In what follows, only an overview is given of those adaptation measures which were made in response to the increased threats from climate change related hazards and impacts.

The proposed adaptation strategy consists of three distinctive phases:

- Phase 1: 2008 to 2025, no extensive protection, no extensive development
- Phase 2: 2025 to 2060, implementation phase
- Phase 3: 2060 to 2100, fine tuning and monitoring

In the first phase the Government of Suriname will continue its activities regarding coastal zone and river bank management, whilst phase 2 will be characterized by implementation of the plan elaborated during phase 1. This will include among other things, stopping all developments and human activities north of the proposed dam, raising the vulnerable area to a status of protected area, continuing riverbank protection against the intruding water, and water management and implementation of spatial planning. Phase 3 is fine tuning and monitoring.

During phase 1 no-regret measures will be implemented along with protection measures, such as stopping further development in the northern parts of the study area and implementing further prevention measures against flooding. The coastal and riverbank protection measures in the existing inhabited areas will be maintained. Retreat will not be considered as a high priority option in this phase. In this phase a detailed adaptation strategy will be elaborated and specific action plans which are ready to implement will be developed.

During phase 2 the adaptation strategy and action plans, including the physical measures, will be implemented. The third and final phase will be focused on fine tuning and monitoring the implemented (physical) measures.

For the development and implementation of the adaptation strategy and action plans a number of essential components need to be considered. Firstly, an enabling environment should be created for supporting the activities taking place in the context of the adaptation strategy. Secondly, a clear spatial plan needs to be developed defining the target use of specific areas. Finally, a number of key adaptation measures need to be considered in order to take early steps in the protection of crucial resources and economic activities in the coastal zone. The different components are discussed in more detail below.

Creating an enabling environment

The elaboration of the adaptation strategy and development of action plans will entail preparatory work in terms of:

- Development of necessary policies and laws;
- Establishment and strengthening of existing institutions and the creation of new supporting institutions (where necessary); and
- Establishment and elaboration of data collection and monitoring systems and increasing research activities and capacities.

It has been recognized that the creation of such an enabling environment will be a necessary condition for successfully implementing adaptation measures.

With regard to the development of necessary policies and laws, consideration should be given to already existing initiatives and documents. Important laws and regulations already exist, such as the Planning Act and Environmental Act. The problem is that these and other regulations are rarely enforced. The Draft Water Law needs to be updated and legislation needs to be put in place to regulate the use of the estuarine zone and natural riverbank (including mangrove vegetation) and to establish spatial planning and land-use policies.

In addition, existing institutions and agencies need to be strengthened and the co-operation between different institutions needs to be intensified and improved. Table 1 gives an overview of the most relevant institutions in terms of climate change and coastal zone management. The table also lists the main responsibilities of the different institutions as well as a summary of areas which need strengthening.

Apart from developing policies and laws, and strengthening institutions and organizations, the successful implementation of a climate change adaptation strategy and action plan will also depend on the availability of good-quality data and information. The importance of valid data has been expressed many times during this and other projects. Lack of data prevents researchers from obtaining in-depth analysis. The purpose of data collection and analysis is to gain insight regarding the current developments in climate change and sea level rise, to identify trends, and to be able to forecast change for a longer period. The following types of data will need to be collected on a regular basis in order to develop consistent and reliable databases:

- Climatic data in the study area;
- Data on the water level in the sea and the lower courses of the Suriname and Saramacca Rivers and wetlands in the study area;
- Data on discharge, stream flow, waves, sedimentation and water quality regarding the water resources;
- Topographical data;
- Data on the dynamics of the coast, riverbanks and riverbeds.

Research capacities will also need to be increased in order to expand the relatively small pool of climate experts in the country. This can, for instance, be done by the establishment of a postgraduate course on climate change in Suriname. The Anton de Kom University will be an important partner in this.

Developing a spatial plan

One of the key elements in the development and implementation of a climate change strategy and action plan will be the development of a clear spatial plan for the districts of Paramaribo and Wanica. As has been mentioned before, building activities and land use changes in Suriname are still taking place more or less randomly and the districts of Paramaribo and Wanica have also been excluded from the list of MUMAs. This has already resulted in the degradation of large areas and uncontrolled building activities in areas vulnerable to flooding and sea level rise. Consequently, various authors have proposed specific planning measures in order to prevent further degradation and to restore the functions of the estuarine zone north of Paramaribo.

Table 1: Overview of key institutions and the areas that need strengthening

Mother Organization	Agency	Duties	Areas that need Strengthening
Ministry of Public Works	**Hydraulic Research Division**	• Collection, processing, analysis and management of data • Execute studies and research • Providing advice regarding water, hydrology and hydraulics.	• Expansion and upgrading, modernizing measuring equipment and operational means • Further training of personnel in modern methods • Further modernization and mechanization of database
	Meteo-rological Service Suriname	• Collection, processing, analysis and management of data • Execute studies and research • Providing advice regarding meteorology and climatology	• Upgrading of the service, including training, instruments and operational means
	Division for Embank-ment Construc-tions	• Construction and maintenance of coastal and river embankment constructions	• Further training of personnel in modern methods for inspection and maintenance of protection works • Training personnel in modern methods for integrated coastal zone and development of coastal zone planning • Mechanize the programming of maintenance of protection works
	Division for Urban Drainage	• Construction and maintenance of urban and primary national drainage system	• Further training of personnel in modern methods regarding urban drainage • Further mechanization of the service
Anton de Kom University of Suriname	**Faculty of Technology**	• Train specialists • Execute research regarding hydrology, hydraulics, meteorology, climatology and environment	

Mother Organization	Agency	Duties	Areas that need Strengthening
Ministry of Labor, Technology and Environment	**Environment Section**	• Development of national environment policy • Monitor execution of national environment policy • Promote environment and sustainable development	
	National Institute for Environment and Sustainable Development (NIMOS)	• Promote environment and sustainable development • Enforcement	
Ministry of Agriculture		• Construction and maintenance of secondary and tertiary infrastructure in agricultural areas • Water boards	
Ministry of Domestic Affairs		• Maintenance of a part of the drainage system in Paramaribo	
Ministry of Regional Development		• Construction and maintenance of secondary and tertiary infrastructure in agricultural areas • Water boards	
Ministry of Spatial Planning and Land Policy		• Spatial planning • Nature conservation	

Proposed measures include:

- Immediately stopping the land issuance north of the northernmost ridge *Suikerrits* on which the Ocean Road is situated and being developed;
- Withdraw any issued land which is not being used, or if it is not being used as agreed;
- Take the following measures on other already issued land, that is in (proper) use:
  - » Do not issue additional building permits;
  - » Give incentives to ensure that:
    - * Mangrove forests remain intact; and

* The re-establishment of the mangrove forests is promoted.

• Prepare a coastal management plan for the Paramaribo-Wanica coastal zone, focusing on coastal protection and considering climate change impacts, including sea level rise.

These proposals have been discussed with officials in charge of MUMA management, but no further steps have been taken yet.

Apart from these specific measures, spatial planning will also require the development of designated zones for natural areas, housing and building, agriculture and industries. In terms of climate change adaptation, the delineation and preservation of natural coastal areas will be particularly important because of the protective role they can play in mitigating the effects of sea level rise. Therefore, a rigid planning strategy will be needed that will ensure the protection of valuable natural zones in the coastal area.

Key adaptation measures

In the course of the project, a range of key technical and non-technical adaptation measures have been proposed and discussed. In what follows, an overview of these adaptation measures is given, including a short discussion of necessary steps that need to be taken in terms of policy, legislation, finance, research, monitoring, data collection, costs and timeframe for implementation.

Measure 1: Stop all developments in the northern part (natural areas) of the districts of Paramaribo and Wanica.

Policy: Change needs to happen so the government should adopt this measure.

Legislation: Appropriate law is required and should be in place to guide the execution of this measure properly. A corresponding legal body is also required and should be put in place as soon as possible.

Finance: Financial investment is necessary. Financial support will also be needed for the compensation of any relocation and/or damage to livelihoods caused by this measure.

Research and Data Collection: Firstly, an appropriate database must be established. Intensive research is required for data collection, including impact studies of the socio-economical aspect. Further research into the development of different scenarios is also required.

Monitoring: Continuous monitoring is a prerequisite for sustainable development. Many problems can be identified during the process of carrying out the measure. For this purpose tools, methods and corresponding training are required.

Data Collection: Without a proper database, identification of needs and limitations will be difficult. Therefore this task is one of the first to be carried out.

Costs: The approximate costs of implementing this measure are high. However, this investment only has to be made once. There are no repetitive costs linked to the implementation of this measure.

Timeframe: Short-term

Measure 2: Intensive in-depth studies and research into the possible impacts of sea level rise.

Policy: Detailed measurement of sea level rise and the topography of the area is required. This is necessary to determine the exact area under threat from the rising sea level. The government needs to adopt this policy in order to ensure its implementation. Lack of data will certainly result in substantial losses, due to the impacts of climate change.

Legislation: No new laws are required.

Finance: No additional financial investment is necessary as the present budgetary levels will absorb it. A joint effort of all the departments, institutions and other beneficiaries could mitigate any additional research costs.

Research and Data Collection: Firstly, an appropriate database must be established. Up-to-date research and data collection is necessary so time and money need investing in this. It may be possible to purchase data such as satellite images from other sources at a cost.

Monitoring: Continuous monitoring of the sea level rise and other developments on the coast and the study area is necessary for sustainable development. Many problems can be identified during the process of the development of the measure or during its initial stages.

Costs: The approximate costs for implementing this measure are relatively high although there is scope for lowering them.

Timeframe: Short-term

Measure 3: Planting of mangrove forests

Policy: This is a relatively new measure but is being used in many parts of the world for other purposes besides enhancing the resilience of the coast. This option as an effective measure against erosion is a no-regret option. Very little or no environmental harm will take place with this measure. The government should promote this option as having advantages over some of the other options in terms of protection of the coast and enhancing the resilience of people and communities living on the vulnerable part of the coast.

Legislation: There is presently no legislation on this matter. Legislation dealing with clearing mangrove forests is urgently required. This law would effectively support the protection of the existing mangrove forests and thus enhance the resilience of the natural ecosystems in the north. Positive results would be achieved by combining this implementation with other measures.

Finance: No additional financial investment is necessary as the present budgetary levels will absorb it. Costs will be incurred from purchasing certain instruments for monitoring parameters and for implementing the measure. In particular, costs will be incurred from the transportation of the mangrove seedlings.

Research and Data Collection: Continuous research and data collection is required to build a database. Since areas are easily accessible no complex problems are expected to rise. Results of this measure would be beneficial for the policy maker in making further decisions. Low costs and high effectiveness of this measure are its biggest advantages.

Monitoring: Continuous monitoring of the planted area is required. This can be done by the local coastal communities under supervision of the research institutes or departments involved.

Costs: The costs are relatively low. Participation of the local communities is required.
Timeframe: Short-term

Measure 4: Construction of river dikes and defenses

Policy: This option is new for the study area and it has been not yet been tried in Suriname. Nevertheless the knowledge required seems to be available. This option is an effective measure against erosion and flooding, but it is costly. Building river dikes and defenses means continuous maintenance. Suriname has seven relatively large rivers, along which human settlements and economical activities take place. Under the conditions of sea level rise many of these settlements will be in danger. So for the study area the implementation of river dikes and defenses is highly recommended.

Legislation: There is presently no legislation on this matter and is therefore required.

Finance: Serious financial investment is required. The present budget is not sufficient to implement this measure and therefore additional funds are necessary. Since this problem is related to climate change issues, financial support from international sources should be sought.

Research and Data Collection: Continuous research and data collection is required to build a database. In particular, areas and river banks that are not affected by economical activities or inhabited should be monitored.

Monitoring: Continuous monitoring is required. This can be done by the local coastal communities under supervision of the involved research institutes or departments.

Costs: The costs are high. Participation of the local and international communities is required.

Timeframe: Medium-term

Measure 5: Constructions of a sea wall and/or groins
Policy: This option is not new. A sea wall is found in the district of Nickerie. It is an effective measure against the erosion, but it is costly. Building seawalls means continuous maintenance. Suriname has a 386 km long coast and therefore policy regarding this measure is required.

Legislation: There is presently no legislation on this matter and therefore it is urgently required.

Finance: The same as mentioned under measure 4 is applicable here. Significant financial investment is required. The government should bear in mind the costs involved in maintaining these defenses.

Research and Data Collection: Continuous research and data collection is required, in particular in coastal areas not affected by economical activities.

Monitoring: Continuous monitoring is required. Involvement of the local coastal communities is necessary.

Costs: The costs are high. Participation of the local communities is required.
Timeframe: Short/Medium-term

Measure 6: A dike to prevent future flooding and sea water penetration should be built further in land.
Policy: This option is presently under review. Care needs to be taken when determining the location of the water retaining dam since many coastal cities are located on the vulnerable coast. Implementation of this measure could seriously affect the local communities and people living in these areas.

Legislation: Taking into consideration the growing pressure on the coastal natural systems, the growing threat and the growing level of vulnerability, urgent implementation of appropriate legislation is required.

Finance: Financial costs could be significant.

Research and Data Collection: Continuous research and data collection is required. Ongoing developments on the coast require permanent documentation.

Monitoring: Continuous monitoring is required. Involvement of the local coastal communities is necessary.

Costs: The costs are medium to high. Participation of the local communities is required.

Timeframe: Medium-term

Measure 7: Relocation of communities
Policy: This option is new and requires serious research. Regardless of if there is available land, the relocation of people would encounter many difficulties, including those of a social, cultural and political nature. It should be mentioned that experiences dealing with annual or frequent flooding of large parts of the country due to heavy rainfall should be seriously considered here. However, the IPCC projections for sea level rise and the uncertainties linked to it are reasons for taking action as soon as possible. The Government should seriously consider this option.

Legislation: Taking into consideration the growing pressure on the coastal natural systems, the growing threat and the growing level of vulnerability, urgent implementation of appropriate legislation is required.

Finance: The same as mentioned under measure 4 is applicable here. Significant financial investment is required, although it would only be a one off payment.

Research and Data Collection: Continuous research and data collection is required. Ongoing developments on the coast required permanent documentation.

Monitoring: Continuous monitoring is required. Involvement of the local coastal communities is necessary.

Costs: The costs are high. Participation of the local communities is required.

Timeframe: Medium/Long-term

These and other measures have also been made spatially explicit in the map in figure 2.

The study area can be roughly divided into the following sections:

Section 1: northern area up to second ridge
Section 2: area covered by the left bank of the Suriname River
Section 3: southern zone of the study area including the Lelydorp
Section 4: middle and western part, including the Saramacca Canal and the Kwatta Ridge.

Section 1: Northern part of the Study Area
This area is the most vulnerable in terms of land loss and areas that will be affected by a sea level rise of 1m. It is sparsely populated, with mangrove forests in the northeast and northwest. Mangrove forests in the middle part of the coastal zone have been almost completely cleared for agricultural purposes. Scattered human settlements are found on the ridges, which in general are located higher than the surrounding clay depositions. Bad natural drainage conditions have led to formations of swamps, deterioration of water quality, ranging from salt through brackish to fresh. Polder structures established in this region have caused subsidence in these areas, thereby enhancing its vulnerability.

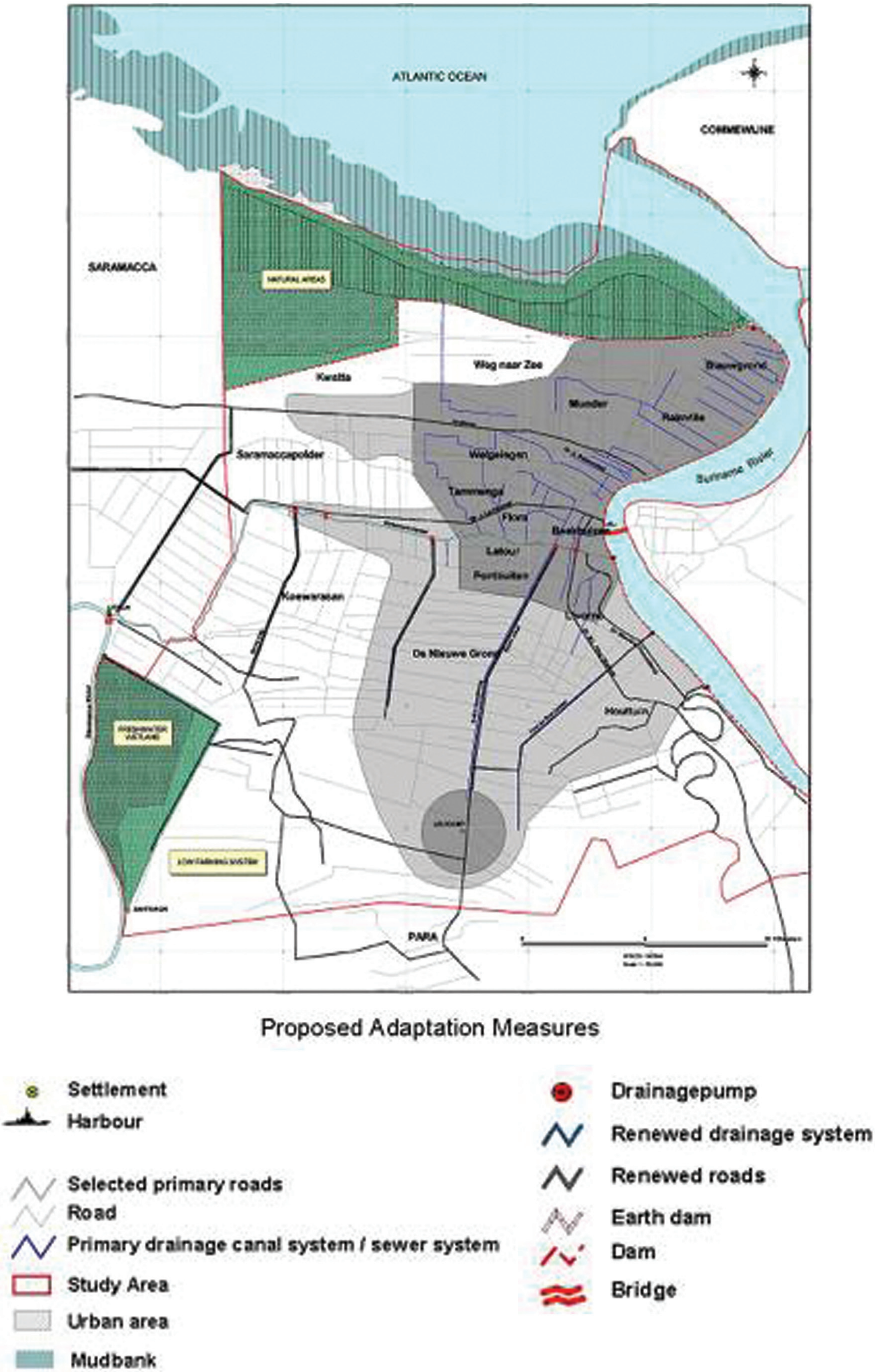

Figure 2: Map of Proposed Adaptation Measures

For this region the following measures are proposed:

- Protection
  - » Soft protection – enhancing resilience of the coastal zone, through:
    - * Creating more space for the shore area;
    - * Creating conditions for mangrove growth; and
    - * Planting mangrove forests.
  - » Hard protection – construction of:
    - * Groins;
    - * Seawalls;
    - * Breakers; and
    - * Other structures.
  - » Construction of earth dams to prevent the urban areas from flooding
- Retreat
  - » The area north of the proposed earth dam will be exposed to sea level rise and should be preserved as a "green zone". People living in this area should be given the opportunity to leave the location within an agreed period of time.
  - » Areas for relocation need to be determined.
  - » Accommodation
  - » This issue is closely related to urban water management. Previously, not enough attention was paid to building regulations in vulnerable areas. This is because the costs involved in building adapted structures are too high to enforce.
  - » The areas most suitable for the implementation of such measures are low lying areas, and river terraces in Paramaribo and north Wanica.

Section 2: Left Bank of the Suriname River

The capital city of Paramaribo is located on the left bank of the Suriname River as are the major port facilities and consequently all major infrastructure. Presently the area is not exposed to erosion except for certain locations where hard protection measures are in place. A substantial part of the left bank is occupied by industries, residences, hotels and other facilities. The lower parts of the left bank have been land filled to reach the present required height for construction purposes. This has resulted in higher elevation than in the surrounding area and therefore functions as a barrier against flooding from high spring tides.

For this section the following measures are proposed:

- Protection
  - » Soft protection:
    - * Preserve the mangrove forests along the river; and
    - * Create conditions for mangrove growth.
  - » Hard protection – construction of:
    - * Groins, if needed;
    - * River wall/dike; and
    - * Other structures.
  - » It should be noted that protection will be required over the whole length of the river bank up to the southern border.
- Retreat
  - » This option is not appropriate here. Therefore it is even more important that regulations are put in place to prevent damage to the riverbank.
- Accommodation
  - » This issue is also related to urban water management. There are no specific measures outlined in this section regarding building regulations.

Section 3: Southern Part of the Study Area Including Lelydorp and the Surrounding Area
This area is characterized by relatively high elevations and relatively poor soil for agricultural purposes. The local town Lelydorp is the capital of the Wanica district and many governmental and other administrative facilities are based there. It is a transit zone between the areas in the north and areas in the south so a great deal of infrastructure for traffic and electricity goes through it.

For this section the following measures are proposed:

- Protection
  - » Soft protection
    - * No soft protection is proposed
  - » Hard protection
    - * No hard protection is proposed
- Retreat
  - » Not applicable.
- Accommodation
  - » This issue is related to urban water management.
  - » The implementation of appropriate spatial planning would be beneficial to this area.

Section 4: Middle and Western Part of the Study Area including Saramacca Canal and the Kwatta Region
This area is characterized by low fertility, abandoned agricultural lands, large open channels and low population density. The Saramacca Canal is the main water way located in the center of the study area and it drains its surplus water into the Saramacca River in the west and the Suriname River in the east. The canal is also important for navigation of small barges and boats.

For this part of the study area the following measures are identified:

- Protection
  - » Soft protection
    - * No soft protection is proposed
  - » Hard protection
    - * No hard protection is proposed
- Retreat
  - » Not applicable.
- Accommodation
  - » This issue is also related to urban water management. The structures such as open and closed water ways, channels, pumps, sluices and other civil engineering structures require proper attention.
  - » Proper spatial planning would be beneficial to this area.

Conclusion and Discussion

The first phase of the NCCSAP concluded that Suriname is highly vulnerable to the impacts of climate change and identified Paramaribo and Wanica as being the most vulnerable districts. In response to these observations, the activities carried out under the second phase of the NCAP have focused on developing a better understanding of the baseline vulnerabilities and on the elaboration of specific adaptation measures for protecting the livelihoods and economic activities in these key districts. In order to do so, the project has carried out a range of sector studies and has organized various meetings and consultations to discuss possible adaptation measures. The main outcome of the project is a set of detailed recommendations and suggestions that can be integrated into a climate change strategy and action plan for Paramaribo and Wanica. The approach used during this project could also be replicated to develop adaptation strategies and action plans for the other districts in the country.

In the course of the project, a few difficulties were encountered which were mainly related to the relative lack of good quality data. In carrying out the sector assessments it was often noted that the necessary data was lacking or not available in the required formats. The lack of good data also made it difficult to develop a complete and clear picture of the vulnerabilities in the two districts. Another issue that has emerged during the implementation of the project is the interrelations between the different sectors. It has been noted that in many cases developments in one sector will affect and have an impact on the developments in another sector. These relationships are not properly understood and new, innovative tools and methodologies will be needed to further explore these relationships.

Regardless of the above-mentioned difficulties the project has achieved its objectives. The project has also proven to be instrumental in increasing the awareness of both policy makers and the general public to the potential impacts of climate change on the study area and consequently more attention is now given to the aspects related to climate change than before. People are, for instance, increasingly considering climate change when making decisions about land use and housing. The project has also had a positive impact on communities and organizations who are now collaborating more on issues related to climate change.

In terms of further steps to be taken, the following key areas have been identified:

Further activities need to take place to strengthen key institutions both in terms of human resources and in terms of tools to carry out tasks and responsibilities.

A spatial plan needs to be drawn up allocating specific areas to specific purposes and activities. Further research needs to be carried out in order to improve our understanding of the role and value of mangrove forests in protecting the coastal zone from sea level rise and other climate change impacts.

Data collection and monitoring systems need to be designed and upgraded in order to facilitate the collection of relevant data about climate change and its impacts on the coastal zone of Suriname.

The Tanzanian Adaptation Program

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1) Introduction

The Tanzanian NCAP report explains vulnerability by exploring the constraints and opportunities that affect livelihoods.

Globally, between one and two billion people live below the poverty line of a daily income of $1, that is around 20% of the global population. The main goal of global development policy is to reduce the level of poverty globally while exploring pathways to achieve this in a sustainable manner. The issue of poverty, and poverty reduction, is particularly acute in the countries of sub-Saharan Africa where many of the most underdeveloped countries are located.

Achievement of food security is amongst the most basic of the needs of any society and it is understood to be a pre-requisite for development to occur. Food insecurity is estimated to affect over two hundred million people in sub-Saharan Africa. Complex linkages exist between agricultural production as a livelihood option and the achievement of food security.

Inequality, whether in economic opportunity, social relations, institutional access or the natural resource base, signifies different levels of vulnerability across a range of areas, for example, inequality exists within households. At a community level, inequality in educational opportunity limits the possibility of marginalized populations to escape the cycle of poverty and vulnerability, although it is also argued that inequality within a localized area may allow for the redistribution of wealth through endogenous institutions.

Examples of global environmental processes that can impact rural livelihoods include enhanced climatic change and variability, land degradation and desertification. Rural livelihoods in sub-Saharan Africa are already threatened by a range of factors, including world trade, HIV/AIDS, and poverty, and this trend is likely to increase in the short to medium term future.

In sub-Saharan Africa, there are a number of diseases that affect livelihoods; the most significant are HIV/AIDS, malaria and tuberculosis. However, the use of unsafe water and inadequate sanitation facilities has a massive negative impact on health, which limits development from the state and regional levels down to the household. At the household level, effects of ill health include bereavement, the loss of labor time and increased healthcare costs. The cumulative effect of these problems on a regional or national level has serious consequences for social and economic development. It can also affect the ability of households to respond to hazards such as drought.

Two national studies were completed which were overviews of agro-ecological zone adaptation, specifically with regard to crops and livestock and water supply issues.

Climatic Change and Variability

Climate change will potentially increase food insecurity for millions of people in Africa. Climate change could result in increased or decreased absolute temperatures and precipitation, and increased seasonal and annual variability. Climate change comes under the hazards paradigm umbrella.

The Hazards Paradigm

Research into the natural hazards paradigm traditionally focused on the actual hazard, potential physical and engineered solutions to the hazard, and perception of the risk. The work of White[1] on flood plain management was amongst the first in the discipline. This research incorporated non-economic considerations, although the focus of the research was mitigation of environmental hazards. This has been termed the "dominant" view in natural resource management, and attaches importance to the causative role of climatic, geo-physical or other "natural" hazards. A significant level of research has also focused on the social, political, economic and legal consequences that may result in or from a hazard. Much research assumes that hazards and disasters are somehow. Insights from human ecology and political economy further explored the influence of human perceptions and action, and structural causes of vulnerability. A focus on the processes that create disasters led to the development of vulnerability as a concept for analysis.

Vulnerability, Resilience and Adaptive Capacity

Vulnerability can be defined in a range of ways for multiple purposes. Füssel categorizes research into biophysical and socioeconomic aspects of vulnerability.[2] Adger argues that it is not possible to separate vulnerability to environmental hazards and change from the vulnerability created by a person or society's relationship with the local, national and global political economy.[3] The need to understand these coupled systems has led to research that explores the concept of "double exposure". Manyena identifies a multitude of different definitions of the term and classifies them on how much they relate to emerging discussions on resilience.[4] The concept of resilience is closely related to that of vulnerability and adaptive capacity.

The concept of resilience emerged from the domains of physics and ecology, and has increased in prominence and practicality in recent years within the social sciences. The concept of resilience is closely related to that of adaptive capacity. Manyena describes it as the ability of communities to "bounce back" after a particular threat; therefore, enhanced resilience enhances the sustainability of livelihood strategies and decreasing resilience increases vulnerability.

This report is concerned with the ability of farming households in Tanzania to adapt to stresses and shocks that affect their livelihoods. The concept of adaptive capacity originated from ecological sciences and has been specifically developed as a term that indicates people's resilience to climate change. Adaptive capacity is associated with the availability of coping mechanisms. A coping mechanism is the means by which a household deals with livelihood stresses and shocks. A useful distinction between adaptation and coping is that adaptation often requires access or entitlement to political power or participation.

1 White, G.F. (1945) Human Adjustment to floods. Research Paper No. 29. Chicago: University of Chicago, Department of Geography

2 Fussel, H.M. (2007) Vulnerability: a generally applicable conceptual framework for Climate Change research. Global Environmental Change. 17: 155-167

3 Adger, W.N. (1996) Approaches to Vulnerability to Climate Change. Global Environmental Change Research Papers. Norwich: Centre for Social and Economic Research on the Global Environment.

4 Manyena, S.B. (2006) The concept of resilience revisited. Disasters. 30(4), 433-450

The Role of Institutions

Research into entitlements strengthened analysis of the role that formal and informal institutions have with regard to the ability of societies and households to access resources necessary to create and sustain livelihoods. The focus on institutions enables an exploration of why certain groups have greater or lesser access to resources and the factors that moderate and control this process. Emphasis on the role of institutions has been particularly successful in explaining how "commons" areas have been managed historically.

Political Ecology

Political ecology is a concept that has increased in prominence in the past twenty years. Political ecology is a method of understanding society-nature relations and analyzing the access and control of resources by different social groups. The political ecology approach has been associated with the development of the livelihoods approach.

Sustainable Livelihoods Approach

Scoones proposed a framework for analyzing sustainable livelihoods:

'A livelihood comprises the capabilities, assets and activities required for a means of living…[it is]…sustainable when it can cope with and recover from stresses and shocks, maintain or enhance its capabilities and assets, while not undermining the natural resource base.'[5]

The principal appeal in using this methodology as a basis for research is that it seeks to combine analysis of vulnerability and how livelihoods are constructed. Specifically, the research explores vulnerability to coupled socio-ecological systems. It is hoped that the output will contribute towards building sustainable livelihoods that are resilient and possess an ability to adapt, and not just cope with threats.

2) Rationale, Objectives and Methods

Rufiji Valley, Tanzania

Resilience and vulnerability in the Rufiji valley of Tanzania are assessed in relation to locally defined poverty indicators and are heavily determined by the availability and access to capital assets.

Spanning 13,339km^2 and situated 192km south of Dar es Salaam, Rufiji is the largest of six administrative districts spread along the coast of the Indian Ocean. The Rufiji district is divided into six smaller administrative divisions, which in turn are divided into 19 wards. In total Rufiji contains 94 villages and 385 hamlets. Rufiji has a hot climate with an average annual rainfall of between 800 to 1,000mm. It has a bimodal rainfall pattern with the short rains between October to December, and the long rains between February to May. Seasonal floods are experienced in the lowlands during the long rains and Rufiji has historically experienced large flood and drought events every ten years. Rufiji is predominantly rural and 80% of households are dependant upon subsistence agriculture. Traditional cultivation methods and tools mean that agriculture is labor intensive and low yielding.

5 Scoones, I. (1998) Sustainable Rural Livelihoods: A Framework for Analysis. IDS Working Paper 72. Brighton: Institute for Development Studies

Climate Change and Variability

Tanzania's Poverty Reduction Strategy Paper identifies the Rufiji district as a high priority because it suffers high levels of food insecurity, malnutrition and poor health statistics. Livelihoods in the region are highly susceptible to stresses and shocks. In the National Communication to the UNFC-CC, climate change scenarios suggest that river basins are expected to receive a 5 to 45% annual increase in rainfall; however, wet seasons are expected to become shorter. Increased precipitation over shorter periods of time will increase the frequency and magnitude of large floods in Rufiji. The dry season is predicted to lengthen, while average temperature increases of 3.5°C will increase the severity of drought.

Predicted climate change impacts will have serious consequences for livelihoods in Rufiji. Increasing frequency and severity of floods will greatly disrupt floodplain livelihoods and cause significant damage to infrastructure (including hydroelectric power generation). Increased rainfall intensity is expected to accelerate soil erosion and nutrient leaching. Higher annual temperatures will increase soil evaporation, shorten the grain filling periods and lead to heat stress in important food crops. Changes to season duration will shorten optimum planting cycles and lead to increased crop failure.

The effects of climate change on biophysical systems in Tanzania highlight the severity of potential impact on livelihoods, which are heavily dependent upon natural resources.

Methodology

Table 1: List of Methodologies

Method	Information Obtained
Semi-Structured Interviews	Entire Household (Size, Age Structure, Education Level, Marital Status & Health Status) Productive Asset Access/Ownership Land Tenure & Practices Off-Farm Income Animal Ownership Flood/Drought Incidences & Coping Mechanisms
Key Informant Interviews	Health, Development & Education Issues Agricultural Practices, Environmental & Market Issues Cultural Practices
Personal Observations	Location, Terrain & Proximity to Physical Infrastructure & Services Land use Changes
Participatory Rural Appraisal (PRA)	Development Timeline Poverty Indicators Off-Farm Income Strategies Daily Calendars (Gendered Labor Divisions) Seasonal Calendars Problem Rankings (by Gender) Solutions Needed
Household Survey	Household Head (Gender, Age, Marital Status & Education Level) Housing, Water & Asset Access/Ownership Agricultural Land & Practices Expenditure & Income Flood, Drought And Diseases Coping Mechanisms

Table 1 details the methodologies used in the Rufiji study. Household interviews, accompanied by key informant interviews conducted in late August 2006 were used to supplement the participatory rural appraisal and household survey.

Results and Analysis

Over 90% of households indicated that they relied upon means other than agriculture to survive flood and drought. All households interviewed indicated that agriculture did not provide enough food to last all year round even during "good" years. Given that agriculture in Rufiji accounts for 80% of all economic activity, this leads to the assumption that households in Rufiji must diversify their labor activities to gain access to food beyond their immediate means of production.

Non-Farm Strategies

A generic list of non-farm activities was generated through Participatory Rural Appraisal ranking exercises (see table 2).

Table 2: Off-Farm Income Strategy Typology

Strategy	High-Middle Income	Middle-Low Income	Low Income
Labor	Temporary/ Permanent Waged Work	Vocational Activity Out Migration	Casual/Unskilled (e.g. Farm labor
Credit Access	Bank Loan	Shop Credit Loan Money/Assets to Others	Little access to formal credit
Market Interaction	Shop (Permanent Structure) selling processed/imported goods	Semi-Permanent Kiosk Selling Cooked Fish & Meat Sell Products to Outside Regions	Hawking/Vending/ Buy to Sell Selling cooked food (e.g. Chapati)
Assets			Sell in Emergency
Assistance	Assist Others		Seed Assistance Receive Shelter Receive Food Receive Remittances
CPRs			Collect Firewood Burn Charcoal Fishing Collect Wild Foods

As defined in PRA exercises and key informant interviews, low income activities such as use of Common Property Resources (CPRs) are widely and simultaneously practiced. Commodities like charcoal are of low value, but 'during difficult periods everyone goes to the forest. Prices drop as a result making it even harder to get by'. Market saturation and low returns make such activities economically unreliable. Reliable daily income coincided with occupying a niche in the market or having access to permanent waged employment.

PRA discussions also crucially revealed how poverty is locally defined by the ability to ensure children receive an education and in the number of meals eaten every day. The poorest households (approximately 50% of residents) are not assured they will eat every day during famine. A relatively poor family (20 to 30%) will survive on one meal per day while middle-income households (30 to 40%) will typically have access to at least two meals. Only the wealthiest households are able to ensure they have access to three meals per day.

With a typology of off-farm strategies and a scale from which to measure poverty, careful analysis through the sustainable livelihoods framework can allow for assessment of the range and quality of coping mechanisms, which either enable or prevent households from resisting and adapting to livelihoods shocks and stresses.

3) Key Results and Findings

Livelihoods

The majority of households in the study area are considered to be very poor and vulnerable with low access to livelihood assets. This is a major concern in terms of food security, poverty reduction and climate change adaptation as poor asset holdings is a major constraint on livelihood diversification and sustainability.

Human Capital

Human capital according to DFID is the primary building block from which other livelihood assets are accessed. The potential for households to access resources is a function not only of the quantity of labor, but the also the quality of labor potential within households. The main factors influencing this include the ability to do work, skills, knowledge and good health. The findings below indicate that in Rufiji, education and health status play an overwhelming part in unlocking other livelihood assets, strongly determining resilience.

Education

Survey data shows that household heads educated at primary level stands at 49.3% while 38.7 % have no education. Only a minority received secondary and further education. The large proportion of those with little or no education is a major issue as education is a vital factor in livelihood generation. The importance of education can be seen through a comparison of two livelihood strategies shown in box 1.

The activities practiced by Household A consist of low income strategies while in Household B there is a mixture of high and middle income band strategies. The key difference in human capital is that no members of Household A have any formal education while the divorced head of Household B has some secondary level education.

Aside from being low income, the strategies practiced by household A are climate sensitive. People who rely on forest resources during the dry season or during severe droughts flood local markets with the same products, so prices drop. The case study demonstrates that educational status improves access to income generation from an ad hoc array of strategies towards more reliable or formal income streams.

Food security is a barrier to education. The poorest are discouraged from sending their children to school because there are no daily meals provided. Parents are often unable to provide children with food and often cannot afford to lose labor by letting children attend. Children who go to school hungry cannot concentrate properly and so do not receive much benefit.

Gender roles are also important determinants of vulnerability in Rufiji. A total of 16.3% of households surveyed were headed by unmarried, divorced and widowed women. Interview and daily calendar data indicate that the division of labor within households is such that women wake earlier and go to sleep later than their husbands as they must attend to domestic and cultivation chores. Men on the other hand spend less time in the field, have more time to socialize and focus on the marketing of crops and charcoal. Given women's predisposition towards socially reproductive tasks, unmarried, divorced and widowed women can be considered particularly vulnerable as time constraints and social norms may act to exclude them from income generation activities usually practiced by men. In addition, female households also face exclusion from essential resources needed to generate a livelihood. The expulsion from her ex-husband's land and home would seriously have compromised the sustainability of Household B had it not been for the good fortunes brought about by her educational background. One interviewee told of her friend from school who was shamed after becoming pregnant while unmarried. She was disowned by her family and friends and ultimately forced to beg for money and food.

Box 1: A Comparison of Livelihood Strategies in Rufiji Valley

Household A
The parents and four children of household A live in a small remote hamlet right on the banks of the Rufiji River. Their home is constructed using mud and coconut leaf thatch, and they cultivate maize and rice over 1.25 acres using small hoes and 'pangas' (bush knives). During good times they will only eat twice per day. As they cannot grow enough food, the father fishes and collects wood to make charcoal. He uses his bicycle to market his goods over several miles and occasionally taxis people and their goods for a fee. When the Rufiji River last flooded they sought refuge in Ikwiriri village using their canoe. Once there, he went fishing to provide an income until the waters receded and they returned to replant and rebuild.

Household B
Household B is headed by a 32 year old divorced woman living with her mother, sister and daughters. The house, built with stone and corrugated iron roofing is connected to an electricity supply and is well furnished with the addition of mosquito nets. She has no access to her ex-husband's farmland and so rents approximately three acres on which she hires tractors and laborers but still cannot form a living off the land. She ensures that her children eat three meals a day, even if she has to eat less. Her main way of making a living comes from part-time work with local NGOs. She also owns a saw wheel, which she lends to others. She says that she is able to secure a bank loan but chooses not to because she wants to avoid debt and interest.

Adaptation in Kilimanjaro: Location of Study Site

Mount Kilimanjaro is a dormant volcano. The mountain has three summits, the Shira plateau in the west, with the Mawenzi and Kibo summits at Uhuru peak point, which, at 5,895m, makes it the highest mountain in Africa. The mountain is iconic and has become a popular tourist attraction. The easier route to the top is dubbed the "coca-cola" route due to its popularity. It is also iconic in the climate change debate figuring prominently in Al Gore's film The Inconvenient Truth (2006).

The Kilimanjaro region is located in northeast Tanzania and covers an area of 13,209km^2, the smallest region in Tanzania. Despite this, it has a population of 2,097,166, giving a population density of 159 people/km^2. The population density varies dramatically from 650 people/km^2 in the highland Chagga gardens to below 50 people/km^2 in the lowland plains. 75% of the population lives in the rural areas and agriculture accounts for 70% of GDP for the region.

There are six districts in the Kilimanjaro region: Rombo; Mwanga Same; Hai; Moshi Rural; and Moshi Urban. Research was carried out in the Chagga gardens of Rombo and Moshi, selected for their ecological similarities and socio-economic differences. Rombo is located in the east of the Kilimanjaro region, covering 1,442km^2 with a population of 417,602; and people/km^2 of 290. The population growth rate is 1.6% while the average household size is 5.6 people. Moshi Rural land area covers 1,713km² and has a population of 504,287 giving it a slightly higher population density of 294 people/km². The population growth rate is also slightly higher at 1.9% but the average household size is lower at 5.4 people.

Although the Uhuru peak is located in the Rombo district, the most popular route to the top starts in Marangu, Moshi Rural district. The sizeable amount of income generated by tourism is mainly concentrated in the Moshi Rural district. This is immediately noticeable, firstly by the better physical infrastructure, and secondly by higher social infrastructure in Moshi Rural. Table 3 demonstrates the comparative levels of infrastructure in Rombo and Moshi Rural. Though there are significant differences, the table does not indicate levels of access to these services throughout both districts. Moshi Rural and Rombo districts have ecological similarities.

Table 3: Comparative Social Indicators of Moshi and Rombo Districts

	Moshi Rural	Rombo
Population with safe drinking water (%)	43	34
Tarmac Roads (km)	103	41
Villages with electricity	51	47
Number of primary schools	193	142
Pupils per classroom	57	74
Number of secondary schools	41	14
Hospitals	2	2
Health centers	6	3
Dispensaries	90	32

There is a national park boundary, largely marked by plantation forests, which starts at 1,800m and extends upwards. This provides a barrier against further population movement up the mountain and is therefore the starting point of the Chagga gardens. The Chagga gardens go down through two distinct highlands and intermediate areas before the lowlands are reached. The highlands are between altitudes of 1,800 to 1,000m, characterized by volcanic soils rich in magnesium and calcium with a wet climate but relatively mild temperature. Traveling down through the gardens there is a noticeable change in morphology, soil structure, garden size, level of precipitation and temperature. The changing bio-physical environment is summarized in table 4.

The highland gardens are traditionally intercropped with trees, bananas, and coffee. They are small in size but rich in diversity. Potatoes, fruit, beans and cassava are the dominant ground crops, and zero-grazing of cattle, goats and sheep is practiced and free-range chickens are kept. The intermediate zone is similar in agricultural produce to the highlands but with increased plantations of maize, bean and sunflower. Soil fertility becomes more varied, and the slopes become gentler. The lowlands sector is typified by a significantly lower amount of rainfall. There is a significant decrease in banana trees and a larger variety of drought resistant crops such as sorghum and finger millet. Stall fed animals are less common but there is range fed livestock.

The region has a bimodal rainfall pattern with the short rains between October and December and the long rains between March and May. Precipitation levels are differentiated by altitude, aspect and exposure on the mountain. Total annual precipitation depends on the success of the short rains and the onset, intensity and duration of the long rains.

Table 4: Changing Characteristics of Kilimanjaro Profiles

	Zone		
	Highlands	**Intermediate**	**Lowlands**
Population density (km²)	600	250	50
Morphology	Sloping hills and plateaus	Gentle plains and moderately sloping hills	Flat plains
Altitude (m)	1,800-1,000	1,100-900	Below 900
Soil	Volcanic – rich in magnesium and calcium	Moderate fertile soil	Variable
Garden size (ha)	0-2	0-3	0-10+
Rainfall (mm)	2,000-1,250	1,250-800	900-700
Temperature °C	15-20	20-30	30+

Climate Change and Variability in the Chagga Gardens

The reason that the deglaciation of Kilimanjaro is not addressed is because there are competing explanations. Some argue that it is increased temperatures due to climate change, whereas others blame local deforestation which has decreased the moisture retention potential of the mountain. Though it is not clear whether the deglaciation will impact the overall water budget of Kilimanjaro, it may affect the number of tourists visiting the area.

Climate change projections for the Kilimanjaro region indicate a 25 to 60% increase in short rain precipitation and an increase of 20 to 45% precipitation of the long rains. Over the past thirty years, the Kilimanjaro region has experienced a general increase in temperature and decrease in precipitation levels (figure 1 and figure 2).

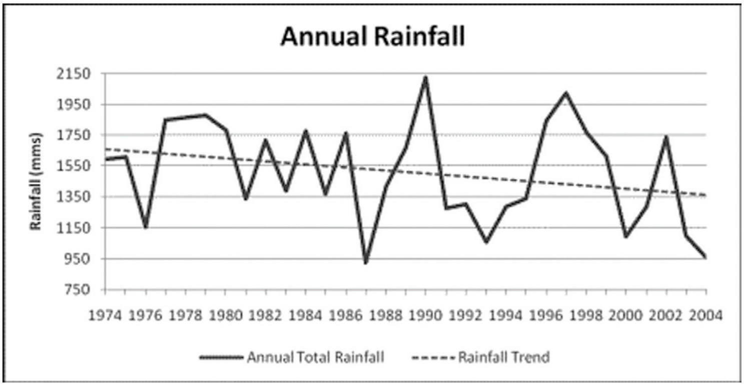


Figure 1
Source: Kilimanjaro Meteorological Office

It is not just mean changes in climatic systems, which will occur, but also increased variability in temperature and precipitation levels. The Kilimanjaro region has always contended with variability. Variability underlies the complex agroforestry system of the Chagga gardens where different tree crop combinations have different responses to climate stimuli. Off-farm sources of income, an echo of the Chagga trading system, serve to counteract variability.

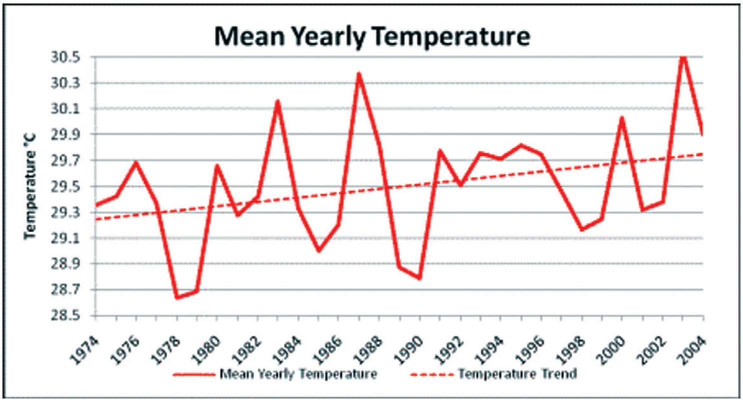


Figure 2
Source: Kilimanjaro Meteorological Office

Figures 3 and 4 illustrate the amount of annual variability connected to the long and short rainy seasons.

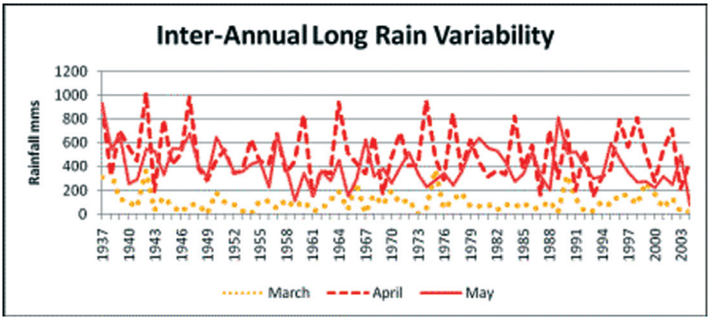


Figure 3
Source: Kilimanjaro Meteorological Office

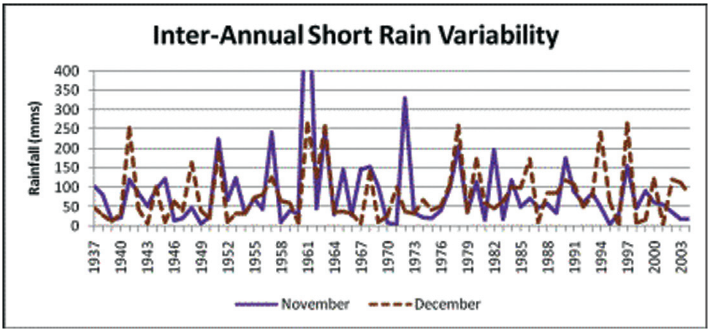


Figure 4
Source: Kilimanjaro meteorological office

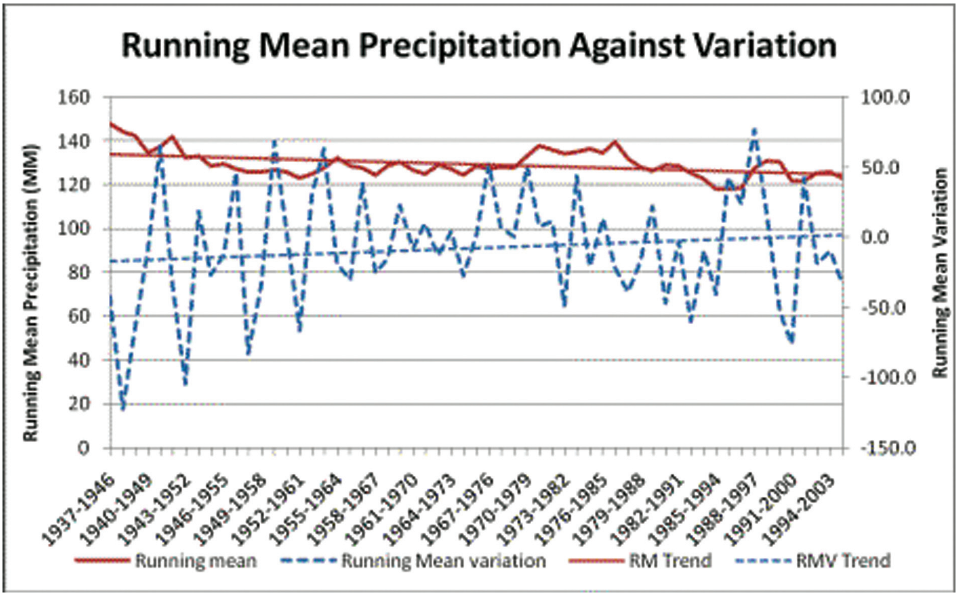


Figure 5
Source: Kilimanjaro Meteorological Office

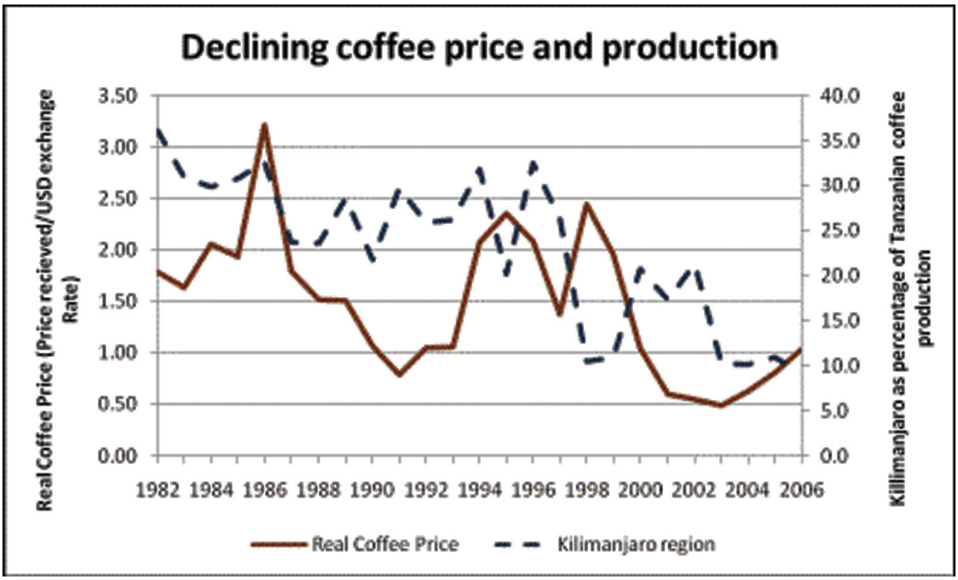


Figure 6
Source: Kahawa House, Moshi, 2007

Figure 5 shows the decadal running mean against variation. It shows that, along with a decrease in annual precipitation levels, there has been an increase in the variability. More variation with lower precipitation levels could increase vulnerability as farmers may have less water available for crop cultivation.

The Kilimanjaro region faces significant risks from climate change, with a rise in mean temperature, and uncertain changes in precipitation levels. The changes are predicted to have both positive and negative effects on agriculture. Coffee and cotton production could be expanded whereas maize production could see a marked decrease. Adaptation should not only guard against adverse impacts but harness the potential benefits of climate change. Adaptation and coping mechanisms should not be considered in isolation of exogenous and endogenous pressures.

Exogenous and Endogenous Pressures

Exogenous and endogenous pressures represent processes that affect vulnerability, although the distinction between the pressures are not fixed as they can operate at different geographic levels. The dominant exogenous factor is the marked decrease in world coffee real prices over the past 30 years. The boom in coffee production from the beginning to mid 20th century allowed for the investment in infrastructure and education in the region. The decline in coffee prices, market liberalization policies, removal of subsidies for inputs and the weakening of the coffee marketing boards have made it increasingly unprofitable to cultivate coffee (illustrated in figure 6). This has resulted in the abandonment of coffee and increased diversification into other subsistence food crops such as maize, potatoes and beans.

Another exogenous pressure is government policy. The national park policy prevents expansion of the gardens to higher altitudes. The Chagga gardens are therefore squeezed between the national park at 1800m and the dry savannah at around 900m. Government policy also influences agricultural production, for example in the crops recommended by extension services.

Endogenous pressures relate to the activities which local stakeholders have more control over. One of the main pressures is population growth, although it is recognized that more people positively impact intensive land use systems as in Machakos. Until recently in the Kilimanjaro region, labor constraints hindered cultivation. More people, however, will require more resources and the population increase is projected to continue in Kilimanjaro.

Pressures causing deforestation are complex. What is acknowledged is that deforestation adversely affects water availability to the Kilimanjaro forest system, water catchment, evapo-transpiration rates, and levels of soil erosion. Sustainable agroforestry has been practiced in the region for over a century, but the increased demand for timber has led to the acceleration of legal and illegal deforestation. The replacement of forest by lowland shrub has already impacted the hydrological balance of the area. The intensification of fire risk is associated with deforestation, along with increased temperature and decreased precipitation.

In the past half century there has been a change in the diet of the Chagga. They have changed from a plantain based diet to maize as the staple food. The change can be attributed to many endogenous and exogenous factors, including the expansion of the maize market.

The Chagga Survey: Issues of Method

The research is based on the findings of 1,000 household surveys along three profiles, east and south of Mount Kilimanjaro. This provides comparison by altitude, aspect and exposure. A pilot survey was carried out in Kiwalla village, which was chosen for its ecological and socio-economic similarities of the three profiles.

Table 5 shows the different data sources assembled. The methodological outline and collection of complimentary data sources allowed for comprehensive research to be completed in the Kilimanjaro region.

Table 5: Range of Data Sources

Data source	Content	Type of data
CEEST survey	1,016 household surveys concentrating on livelihoods	Primary
Secondary survey	Conducted on the same profiles, but regarding the actions of formal and informal institutions during "normal" times and times of *njaa* (hunger); 100 households were involved. A separate questionnaire focused on respondents' perception of coffee; 100 households were involved.	Primary
Seasonality calendar	This was constructed with help from local farmers.	Primary
Women's focus groups	One hour interviews were conducted with a range of women from different socio-economic backgrounds.	Primary
Key informant interviews	They were conducted with local government officials and NGO representatives.	Primary
Physical asset checklist	A mental checklist was used to try to differentiate between levels of income between households.	Primary
Structured observation	Carried out when monitoring enumerators	Primary
Theoretical context information	Over 500 articles were collected allowing a development of theoretical context.	Secondary
Location setting information	Local data on climate, coffee prices, socio-economic and physical infrastructure was collected from local government, private and public offices.	Secondary

Location and Differentiation of the Chagga Survey

Three profiles were chosen for their ecological and socio-economic differences. These were the Rombo profile in the east and the Marangu and Old Moshi profiles in the south. 519 surveys were conducted in the Rombo profile, 379 in the Marangu profile and 118 in the Old Moshi profile. This allowed comparison of height, quality of infrastructure and access to physical capital. Figure 7 is a graphical representation of the Rombo profile and serves as an example for the other profiles.

The profile stretched over four miles and decreased in altitude from 5,700 to 3,700 feet. Rombo A and B were mostly banana and coffee plantations with a diversity of subsistence food crops and an increasing amount of maize further down the profile. In Rombo C, the change in food crops was noticeable and largely attributed to water availability. The banana plants were considerably smaller or replaced by drought resistant crops such as sorghum, finger millet, maize and cow peas.

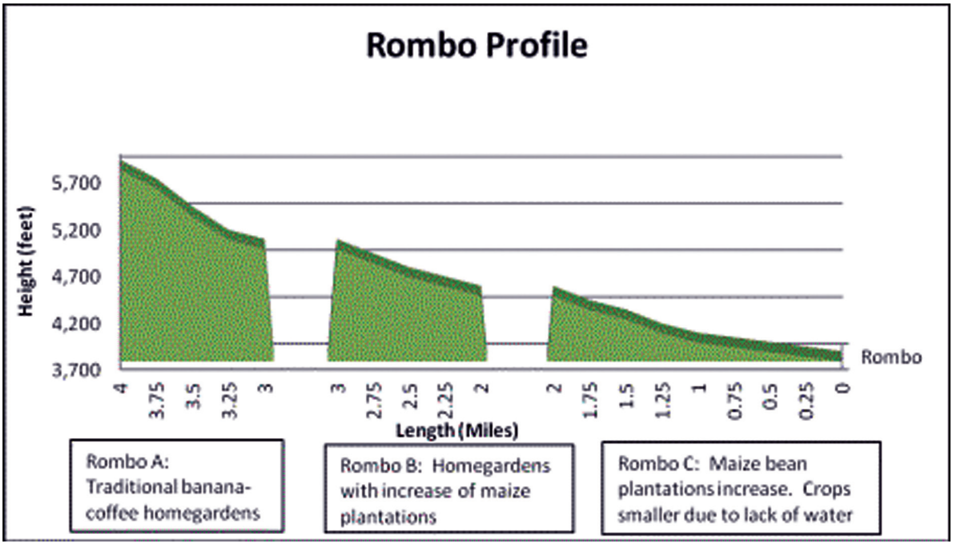


Figure 7
Drawn from Rombo, 1st Edition, Directorate of Overseas Survey, 1963

Rombo A and B population density is 480 to 500 people/km² and the annual rainfall is between 1 000 and 1,750mm. Rombo C has a population density of 280 to 320 people/km² and the annual rainfall is considerably lower compared to the higher lands with a range between 725 and 1,250mm.

Lessons Learned

Results and Analysis from the Chagga Survey

Over 90% of the respondents stated that a bad year meant either a bad harvest or insufficient food for the family. This suggests that the population are primarily subsistence farmers. For bad year indicators, over 80% mentioned a rainfall variation as a pre-curser to a bad year.

Over 50% of the interviewees were men. The age of the respondents reflected the general demographics of the area with 23% between the ages of 18 and 37, 42% were aged between 38 and 57 and 35% of the participants were above 57 years of age. When asked about their marital status, 76% indicated they were married with 13% of the population widowed. Over 77% stated that they were farmers. 73% of the respondents have primary education, 12% have secondary education and a further 2% have college or university education. However, the general description of age, gender, occupation, marital status and educational level conceals huge variation in socio-economic status between respondents.

Table 6 displays income profiles for Rombo and Moshi Rural. It becomes clear that Rombo relies more heavily on agricultural produce and less on off-farm activities and remittances. Coffee and bananas form a sizeable amount, 42.9%, of the income portfolio in Rombo compared to 10.1% in Moshi Rural. Off-farm income and remittances account for 62.9% of income from Moshi Rural compared to 43.4% in Rombo. It is likely that Rombo is more vulnerable to climatic shocks and stresses than Moshi Rural due to lower income from off-farm activities and less diversified livelihood options.

Table 6: Income Portfolio (2006) by Profile

Rombo	/=	%	Mochi Rural	/=	%
Coffee	30,759	14.8	Coffee	13,676	2.5
Maize	6,592	3.2	Maize	33,681	6.2
Beans	1,634	0.8	Beans	5,711	1.1
Millet	2,295	1.1	Millet	218	0.0
Sunflower	944	0.5	Sunflower	1,836	0.3
Bananas	58,294	28.1	Bananas	41,237	7.6
Other	3,251	1.6	Other	53,430	9.8
Livestock	8,106	3.9	Livestock	40,58	7.5
Wood	1,549	0.7	Wood	5,434	1.0
Fruit	2,515	1.2	Fruit	6,898	1.3
Remittances	35,102	16.9	Remittances	71,348	13.1
Off-farm	54,972	26.5	Off-farm	270,421	49.8
income Total	207,585	100.0	income Total	542,596	100.0

The income portfolio also differs by gender (table 7). The mean male income shows that a higher percentage obtain income from coffee and livestock than females. Traditionally, coffee revenue was controlled by men and livestock by women. The reduction in the profitability of coffee has resulted in men taking over traditionally female income streams. Women receive a larger proportion of income from remittances. This is to be expected where male migration and remittances support the rural household.

Table 7: Comparison of Male and Female Income Sources

Mean Male Income			Mean Female Income		
Source	/=	%	Source	/=	%
Coffee	28,970	8.0	Coffee	14,393	3.8
Maize	21,870	6.1	Maize	17,970	4.7
Beans	4,098	1.1	Beans	3,196	0.8
Millet	1,488	0.4	Millet	1,052	0.3
Sunflower	1,199	0.3	Sunflower	1,637	0.4
Bananas	48,743	13.5	Bananas	51,226	13.4
Other	928	0.3	Other	1,673	0.4
Livestock	27,161	7.5	Livestock	22,164	5.8
Wood	5,281	1.5	Wood	1,404	0.4
Fruit	4,447	1.2	Fruit	4,988	1.3
Remittances	36,644	10.1	Remittances	73,337	19.2
Off-farm	182,175	50.4	Off-farm	139,958	36.6
income Total	361,361	100.0	income Total	381,961	100.0

Access to water is a basic need, and time spent collecting water can detract from other livelihood activities. If children are asked to fetch water then this can hamper educational development due to a reduced amount of time for study and through physical exhaustion. Figure 8 shows differences in access to water sources by different areas. Marangu has the highest percentage of piped water in the home, explained by the relative wealth of the area. Lower Moshi has the least access to water as they have the highest percentage of people dependent on wells, dams, rivers and streams. Rombo C, a comparable lowland area, has the highest proportion of people accessing water through piped water at the home or from a neighbor. The disparity may be explained by the water initiatives introduced by Kiliwater Company Ltd. to increase the level of household water metering.

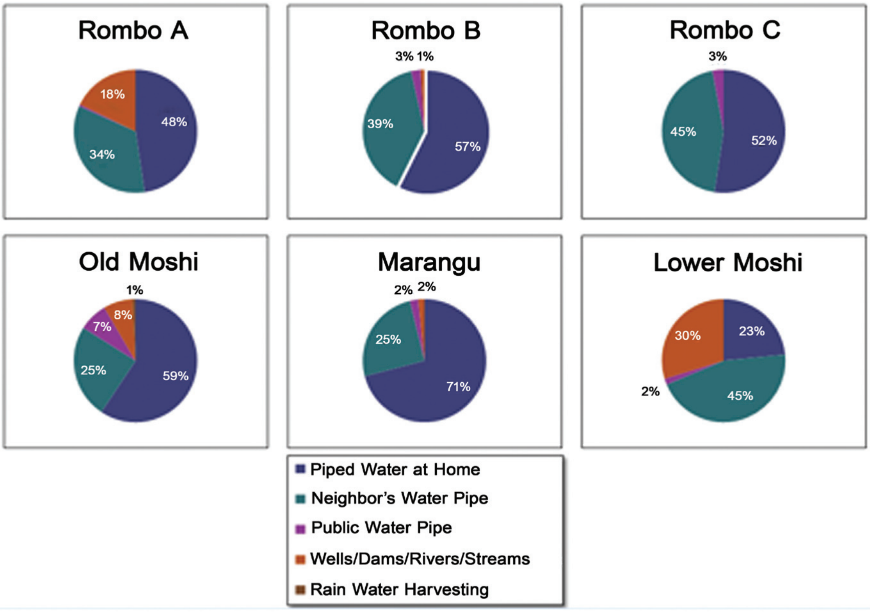


Figure 8 Differences in Access to Water Sources in Various Areas of Tanzania

Education determines the availability of livelihood options. A large percentage of the population is educated to primary school level, but there is a sharp decrease in attendance at secondary school and tertiary levels. This is due to a lack of funds to pay for school fees, uniforms and other equipment. The data shows that as education levels increase so does the percentage of people who gain information from agricultural extension officers (table 8). This may be because people who enter advanced stages of education do not inherit the knowledge of farming practices obtained by working the farm. Another, more probable, explanation may be that there is a social network of graduates, including extension officers.

Over 90% of the respondents stated they were aware of climate change. Out of these respondents nearly 80% mentioned shorter rain seasons, insufficient rainfall or both as an impact of climate change. This runs parallel to the meteorological data collected, which shows an overall decreasing amount of rainfall

Figure 9 illustrates differing perceptions of drought experience against total amount of rainfall. It shows that 1983 to 1984, when there were two years of below average rainfall, was the drought that most age groups recalled. The older age groups reported in larger numbers that 1984 was the last drought primarily because younger respondents were not born yet or could not remember. The number of respondents who mentioned that drought had occurred in the last five years increased dramatically. But this seems to be more an issue of food security rather than meteorology.

Table 8: Education Level and Extension Services Access

Source of Information	Level of Education (%)					
	No Schooling	Adult Education	Primary Education	Secondary Education	College/ University	Total
Agricultural Extension Officer	23	20	32	44	50	32.6
Other Farmers	28	40	32	20	9	30.1
Seed Suppliers	0	0	4	10	18	4.8
Media	4	3	4	5	5	3.8
Nowhere	45	37	28	21	18	28.8
Total	100	100	100	100	100	100

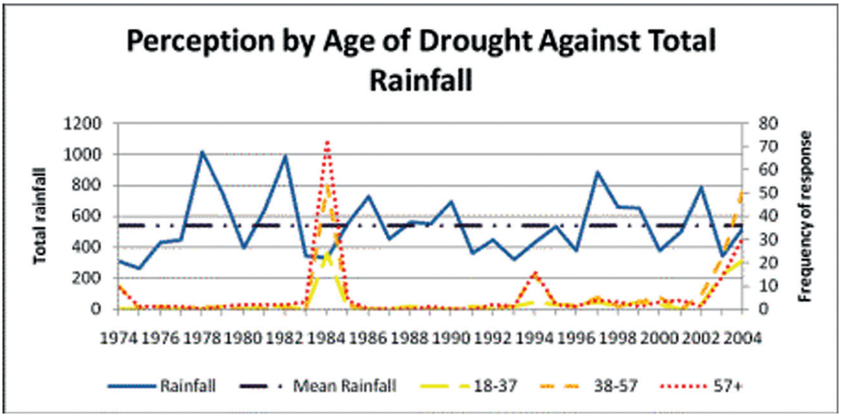


Figure 9

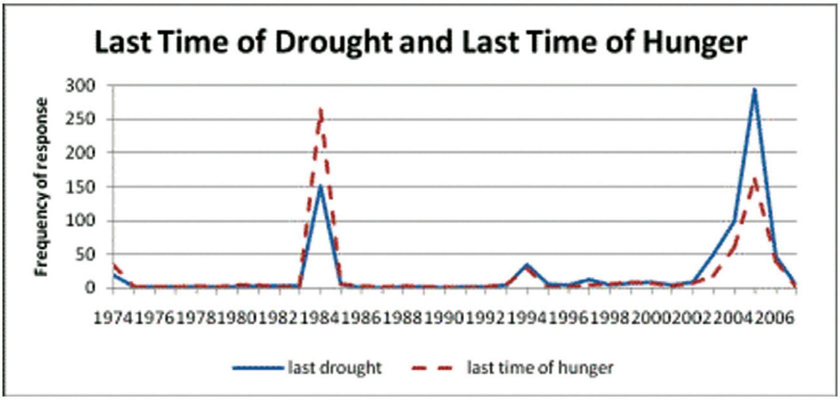


Figure 10

Food security in Kilimanjaro often depends upon a combination of diverse livelihood options that can be used to nourish the family. Figure 10 shows the instances of people stating the last time of drought and also the last time of *njaa* (hunger). This graph shows that in 1984 the number of people who reported the last time of *njaa* was considerably higher than the number of people who reported drought. In 2005 it was quite the opposite, with a large amount of people reporting drought and fewer people reporting *njaa*. What this demonstrates is that there can be *njaa* without drought and drought without *njaa*. It also suggests that peoples' coping mechanisms may be improving. The social network is usually the fastest to respond to impacts of drought, namely food insecurity, while the government response is usually several weeks behind but still essential.

Coping mechanisms exist to address food insecurity, and typically involve gifts in kind or loans from friends or family, the sale of livestock or the cutting down of trees to raise capital. Coping mechanisms can also adversely affect adaptation strategies; people become unable to repay debts, there is no produce from livestock, and the trees, which provided shade for other crops and had other end uses, are no longer available.

Adaptation Strategies

The difference between adaptation and coping mechanisms is that coping is done through existing systems whereas adaptation occurs through the modification of the system. Small-holder farmers are frequently perceived as efficient, experienced and fundamentally adaptive. This is illustrated by the dynamic climatic conditions on Mount Kilimanjaro and the ability of the Chagga to transform the forested foot hills into inhabitable dwellings through years of cultivation, selection and cultured management of the land. Of course this does not imply that all small-holder farmers are sustainable land managers but by looking at the set of assets, skills and opportunities which they possess, much can be learnt about the adaptive capacity of an area.

The adaptation strategies of the Chaaga in response to both the exogenous and endogenous pressures can be split into three broad categories, extensification, intensification and diversification into off-farm activities.

The potential for extensification of the Chagga farming system is constrained by a number of factors. The upper limit of the homegarden system is the Kilimanjaro National Park. Although there is the presence of a "half-mile strip", that is jointly controlled and managed by local and national authorities, and the possibility for clearance and settlement on higher altitudes does not exist. At the lower reach of the system, described as savannah two decades ago is now almost entirely under cultivation. This is either in the form of lowland farms that are usually a mixture of maize, sunflower and beans, or an attempt to replicate the Chagga homegarden system on less watered and fertile land further down the slopes. The former system has existed longer historically, and is based around crops that are perhaps more suited to this agro-ecological zone. The latter system, as demonstrated by the poor quality of banana plants and other crops when compared to higher altitudes, makes it unlikely that livelihoods can be sustained in these areas by on-farm activities alone. The lack of available land on the mountain, and the difficulty of accessing plots that may be a significant distance away from the homestead, suggests that opportunities for extending the system are severely constrained.

In the higher and middle zones of the Chagga homegardens, potential for intensification is limited by several factors, mainly the unfeasibility of mechanizing production on steep slopes and the difficulty of obtaining chemical inputs, either through lack of credit to purchase or removal of previously subsidized supply. Other intensification options include indigenous forms of terracing, utilization of improved seeds, increased application of manure and compost, cultivation of higher value agroforestry species, and higher yielding livestock varieties. Although potential for improvement exists in all these areas, the burden of risk in any intensification process is placed almost entirely on the farmer. When the inherently variable climate of Mount Kilimanjaro is factored in, the risk burden is probably unsustainable and outweighs the potential benefits.

Diversification into off-farm activities has been occurring for over a century on Mount Kilimanjaro, from migration to more fertile lands to provisioning caravans. More recently, the coffee revenue has provided the opportunity for a large number of people to be educated to a high level. In general, the more education a person receives, the greater their livelihood options. Levels of migration occur at the local, regional and national level. At the local level a farmer may work on his neighbor's field to gain extra income. There may be regional migration to Moshi and Arusha as well as national migration, with remittances sent back to the household. Job opportunities related to provisioning of tourists ascending Mount Kilimanjaro are available but strong competition exists. This is demonstrated by the disparity in off-farm income between Rombo and Moshi-Rural. Transportation, and the level of physical infrastructure partially determines the prospects of generating off-farm income as it dictates access to more profitable agricultural markets and employment opportunities.

Capital Asset Pentagons

The different capital assets were numerated so that five indicators were selected to represent each capital, and given a mark. Zero signified minimal, or no access or command of a particular capital and two signified complete, or almost complete, access or command of entitlements. A mark of one was given if the level of asset was thought to lie somewhere between these poles. These marks were graded in a model (0 to 10) for each capital asset. Figure 11 is a graphical representation of the level of capital assets in the case study location.

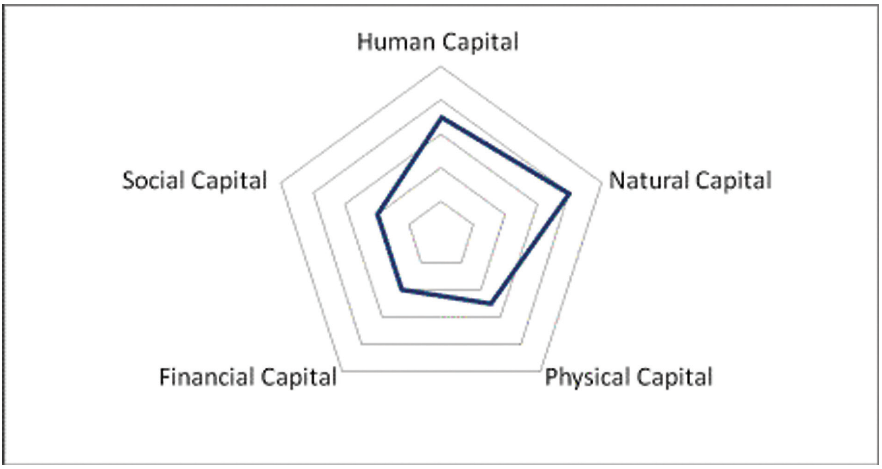


Figure 11: Capital Asset Pentagon

Human capital is relatively high in the Kilimanjaro Region, especially when compared with other parts of Tanzania. Primary school enrolment is amongst the highest in the country, and virtually everyone has access to healthcare, although the quality and availability of this varies significantly. Potential opportunities for human capital enhancement exist in increasing the number of people who obtain at least a secondary education and improving access to and quality of the extension service. Constraints include financing an expansion of both secondary education and the extension service. The level of natural capital in the case study location has been shown to be high, and particularly important in the livelihood construction of those households that do not have access to significant sources of off-farm income. As the levels of biodiversity and biomass in the Chagga homegardens play an important, if not defining role in the water management system on Mount Kilimanjaro and its foothills, the possibility of payment for ecological services should be investigated further. A potential method for financing this would be through an international facility such as the Clean Development Mechanism. The major constraints for enhancing natural capital in the area are the previously discussed restrictions on intensifying and extensifying the homegarden farming system, and sourcing sustainable funding for the concept of payment for ecological services.

The quality and quantity of physical capital, particularly infrastructure, varies markedly between districts in the case study area. Although there are relatively high levels of infrastructure when compared with other parts of Tanzania, the areas with greater stated income generally had higher levels of infrastructure. This was observable for public assets such as roads as well as personal assets such as private water pipes. A process which will be completed within three years in the Rombo District, to tarmac the road to the Kenyan border, is the greatest opportunity observed for enhancing physical capital. The primary constraint to expanding physical assets elsewhere is the high initial and ongoing expenditure. Individual indicators of physical capital are likely to increase as a result of increases in other capitals, particularly financial capital.

Over half of financial capital generation on Mount Kilimanjaro is from off-farm income sources including remittances. Therefore, a focus on opportunities to increase the level of off-farm income, particularly for those households in the Rombo District, is a potential pathway to enhancing financial capital. An example of how this could be achieved is through the promotion and support of local businesses. There is potential for increasing on-farm production, particularly with regard to adding value to primary produce, and increasing output and consequentially financial returns, through intensification of agricultural and agroforestry activities. Commensurate to all these goals is the possibility of expanding various forms of micro-finance and micro-credit schemes, which are currently accessible by a small minority of households. Constraints are the high level of investment required when instigating these schemes and the increased burden of risk placed on households if appropriate safety nets are not also enacted.

Social capital, particularly in the form of informal networks, has declined in importance from the pre-colonial era. Those households in the lowlands that may be considered most vulnerable to the effects of drought rely more on formal government support in times of need than the relatively wealthier respondents further up the mountain. Opportunities for enhancing social capital are likely to be greatest in supporting and funding local NGOs, CBOs and formalizing local institutions. An example of this is the work Envirocare, a Tanzanian NGO, is doing with women's groups in the Kilimanjaro Region. Collective action can provide the individual members with greater income generating opportunities, with regard to both on-farm and off-farm capital generating activities. Ensuring sustainable funding, the initial capital requirements to create these groups and problems with ensuring equal access are the main constraints to enhancing social capital.

Existing Response Mechanisms

Research was undertaken into the *njaa* (hunger) response mechanism from the government. This may be regarded as a powerful institutional mechanism to address potential famine. Unlike neighboring states, Tanzania has not declared a famine emergency since independence. There was consensus among government officials interviewed that distributions should not be free. Arguments ranged from those of one district head 'nothing is free nowadays' to more considered arguments about creating dependency. Unfortunately, certain interviewees took the dependency argument to the extent of accusing farmers of not preparing for *njaa* as they have a 'mindset that it's laborious, and they can easily get food relief'. This may be partly explained as part of an 'official policy in agriculture of food self-sufficiency'. Further, the consensus on the appropriateness of paying for food aid among government officials must in part be due to the fact that districts must pay for maize from the Special Grain Reserves (SGRs) and for logistics costs themselves, so must recover these costs somehow.

Overall, the system is aimed at providing food to prevent starvation. Since food insecurity begins long before malnutrition and starvation become evident, the system will always respond late and do nothing to positively build resilience before the event. Preventative measures carried out by other bodies do little to build resilience due to scarce resources, leading to heavy reliance on a system set up to relieve “famine” in the sense of starvation leading to death. Although the system does not take account of other stages in food insecurity, it does seem to function well at preventing starvation fatalities. Given the small budget available this may be the only level of safety net the government can afford and the system does a fairly good job of reducing vulnerability to starvation, despite some major effectiveness and appropriateness issues. The system also does not contain any preventative aspects (despite the availability of good early warning indicators). In order to be truly appropriate the system must integrate prevention and response in order to build resilience and prevent *njaa*. Although such links do not formally exist, overlap of staff and responsibility mean in practice there is a strong link to the extension service. However, the ability of the extension service to function has been severely curtailed by budget cuts associated with the “good governance” agenda imposed by donor institutions.

Increasing the quantity of individual capital assets can affect the level of other capitals. This can occur in a positive manner, for example, increasing information on good practice farming techniques increases human capital which in turn enhances levels of natural and financial capital. An increase in physical capital could provide better access to markets and more reliable sources of water, with positive effects for levels of financial and human capital. Increasing social capital might improve dissemination of best practice, provide access to appropriate tools and strengthen the position of producers which could potentially increase levels of human, physical and financial capital. This process, however, could work in the opposite direction. Enhancing human capital may persuade people that improved livelihood options exist away from the homestead, with subsequent negative effects on natural capital. Increasing financial capital through additional sources of off-farm income could reduce the quantity of natural capital through neglect of the farm. This is turn could affect human capital through a reduction in location specific agricultural knowledge and could negatively influence social capital because of a lack of previously shared common interests between households. Therefore, interventions must be carefully considered for all potential consequences.

World prices for primary agricultural products are falling while the real cost of production is rising. The impact on the Chagga gardens is a significant decline in coffee production, leading some farmers to uproot bushes for other products in the agroforestry system. The farmers have no opportunity for expansion although intensification of the agroforestry system, including a return to revamped coffee production and processing industry, offers a real opportunity. On the drylands, which seem to be particularly affected by a local fall in precipitation, sorghum and millet should replace maize as they are drought resistant carbohydrate staples. The most significant opportunity, however, is likely to be the continued expansion of off-farm formal and informal employment and increased entrepreneurial activity to generate small businesses. The climate might be changing but not perhaps as fast as the Chagga livelihood system.

Conclusion

When considering adaptation options it is important to differentiate between genuine adaptive measures and an expansion in coping mechanisms that are already prevalent. Coping mechanisms occur within existing institutional and power arrangements, whereas adaptation often involves modification of the structures in which the transformation of livelihood takes place. As the most vulnerable groups are generally those with relatively low levels of capital assets, and also affected more by shocks, trends and seasonal factors, they would presumably be the people who would benefit most from successful adaptation measures. However, if they are also the groups who possess the least levels of political capital then what options exist other than an expansion of their existing coping mechanisms? Without the ability to access and change institutional structures that have a bearing on their own livelihood construction, adaptation remains a concept that can only be imposed through top-down, external structures. The focus should be on enhancing the resilience of vulnerable societies, through disaster risk reduction and capacity building approaches. This could enable a level of preparedness and response to biophysical hazards that is currently not achievable. As for existing adaptation routes, the strong message that comes from both the Rufigi and Kilimanjaro fieldwork is that access to work, usually in urban areas, is what keeps these rural livelihood systems resilient. Under conditions of climate change, there is an urban solution to the problem of rural risk.

Climate Change Impacts in Huong River Basin and Adaptation in its Coastal District Phu Vang, Thua Thien Hue Province

Le Nguyen Tuong, Tran Mai Kien, Tran Thuc and Tran Quynh

1. Introduction

Located in Southeast Asia, with a tropical monsoon climate and a coastline of more than 3,260km, Vietnam is one of the most disaster-prone countries in the world. Most of the disasters that occur in the country are related to weather and climate, and consequently climate change and climate variability are likely to pose increasing threats to Vietnam and its inhabitants in the near and long-term future.

Climate change is not only an “environmental” issue; it already poses a wider threat to the sustainable development of Vietnam, having impacts on all sectors and regions of the country. In fact, the potential impacts of climate change on Vietnam are considered to be a very serious challenge to national efforts towards hunger eradication, poverty reduction and sustainable development. The sectors most vulnerable to climate change have been identified as: natural resources (water, land, and biodiversity); agriculture and aquaculture; energy; transport; and public health.

According to a recent assessment by the World Bank Vietnam is among the five most vulnerable countries to the impacts of climate change and consequent sea level rise. The strongest impacts are likely to be experienced in the low land delta (the Mekong River delta in the south and Red River delta in the north) and coastal areas. With a projected sea level rise of 1m by 2100, about 10% of the Vietnamese population would be directly affected and GDP would decrease by the same percentage. If the projected changes come to pass, approximately 40,000km^2 of the coastal areas and deltas would be inundated every year, including the complete swamping of about 80% of the Mekong River delta’s area.

Even though more and more people are starting to become aware of the potential threats posed by climate change, climate change is also a relatively new and complicated challenge, which may cause short-term impacts and enormous potential risks and uncertainties in the future. Although the people of Vietnam have thousand year old traditions of confronting and overcoming a variety of natural disasters, identifying adaptation options to climate change at different scales may require new approaches.

It is in this context that the Institute of Hydrology, Meteorology and Environment (IMHEN) and the Department of Natural Resources and Environment (DONRE) in Hue developed and implemented the project ‘Climate Change Impacts in the Huong River Basin and Adaptation in its Coastal District Phu Vang’. The project was part of the second phase of the Netherlands Climate Assistance Program and took place from 2005 to 2008.

The main objective of the project was to strengthen the capacity and preparedness of the different sectors, organizations and people in Vietnam to adapt and respond to the changing climate. A particular focus of the project has been on water resources and hydrology at the basin level, as well as a deeper investigation into adaptation issues at the local level. Thua Thien Hue Province, the Huong River Basin and Phu Vang district in Vietnam were chosen for this pilot study. Through this, the project also tried to contribute towards the implementation of Vietnam's national strategy for poverty elimination and sustainable development. The results and findings of the project may be further analyzed to develop a participatory climate change adaptation and integrated water resource management model, which can be used in other basins and areas nationwide.

Specific objectives of the project were:

- To combine water flow modeling for an entire river basin with participatory management tools for a coastal district or village.
- To study existing and future climate change impacts on water resources in the river basin and understand how poor people's livelihoods depend strongly on climate and water resource changes.
- To improve awareness, a proactive attitude and preparedness regarding climate change and its impacts among all related stakeholders, especially the local authority and policy makers and the most vulnerable communities.
- To understand local customs and indigenous knowledge regarding weather, climate and disasters and assess and improve existing adaptation measures with stakeholders' participation.
- To prepare and develop, with stakeholder participation, the optimal feasible adaptation plan and policy at district level with a view to replicate them at provincial and national levels.

The remainder of this chapter will provide an overview of the background and approach of the project as well as some of the key results and findings in Vietnam. As it is not possible to present all the results and findings in this chapter, the reader is referred to the various technical papers for more information on specific aspects of the project. The chapter will end with a short summary of recommendations and lessons learned.

2. The study area and methodological approach

2.1 The study area: Thua Thien Hue Province, Huong River Basin and Phu Vang district

Thua Thien Hue (TTH) is a province in the coastal zone of northern central Vietnam, located between 15059'-16048'N and 106025'-107051'E. It is bordered on the east by the East Sea of Vietnam (South China Sea) and on the west by Laos (figure 1). The province has a varied geography including forested mountains and hills, rivers, streams, (rice) paddy fields, coastal lagoons and marine areas. Lying on the east–west corridor connecting Myanmar, Thailand, Laos and Vietnam with the South China Sea, Thua Thien Hue is one of four provinces of the Central Key Economic Zone and is one of the most famous cultural and tourism areas of the country.

Thua Thien Hue has an area of 5,053km^2 and is divided into nine administrative districts. In 2006 the population of the province was estimated at 1,150,000 inhabitants, with about 300,000 of these living in or around the ancient capital of Hue. Much of the province's infrastructure and industry lies in the coastal plain and most of the population lives within 25km of the coast. As such, Thua Thien Hue is at high risk from disasters and other climate change-related impacts.

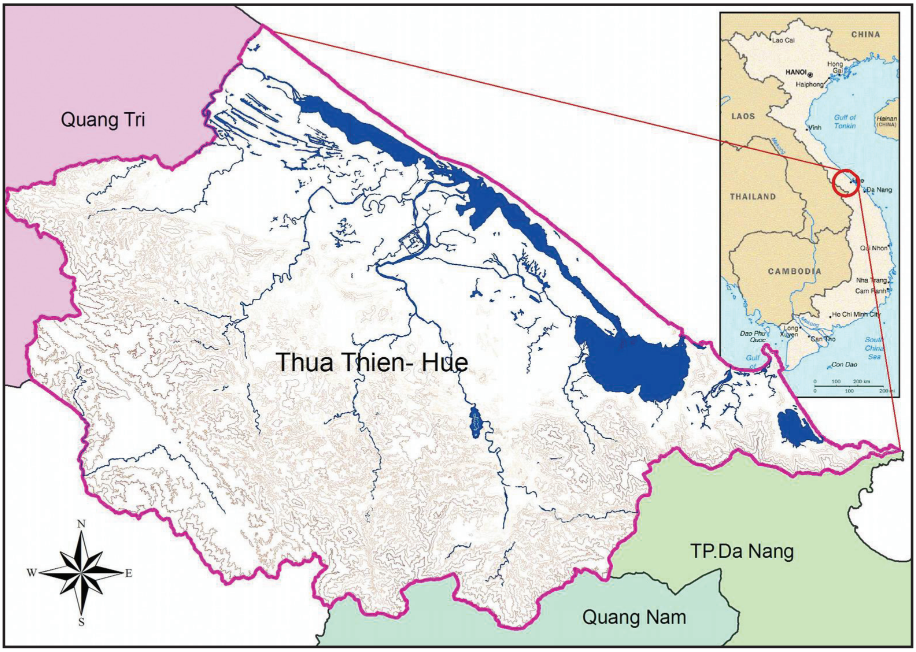


Figure 1: Location of Thua Thien Hue Province in Vietnam and the Surrounding Regions

The *Huong River Basin* is the largest basin in Thua Thien Hue Province. It has a length of 104km and three main tributaries: the Ta Trach, Huu Trach and Bo Rivers. The total area of the basin is approximately 2,830km^2, among which more than 80% consists of mountainous and steeply hilly terrain (the average basin altitude is 330m and the average basin slope is 28.5%). The Huong River Basin is located in the specific monsoon climate zone of central Vietnam with a severe meteorological regime: a long dry season followed by a short rainy season with often very intense rainfall. Almost all of the record rainfalls measured in Vietnam have been in the Huong River Basin. The highest rainfalls on records are in Thua Thien Hue: daily – 731.3mm, monthly – 2,451.7mm and annual rainfall – 5,910.7mm.

The Huong River Basin contains a unique ecosystem of national importance – the Tam Giang-Cau Hai lagoon, which is the largest lagoon system in Vietnam and in southeast Asia. 24,876ha of the Tam Giang-Cau Hai lagoon were included on a list of 16 proposed wetland and marine protected areas in Vietnam in 1998. However, due to the changing environment and poorly planned expansion of the aquaculture sector, the ecological integrity and water quality of the lagoon system has rapidly degraded. In addition, construction of a major anti-salinity weir in the Huong River is decreasing downstream freshwater flows and is impacting on the fauna and flora in the lagoons.

The Huong River is also the main source of irrigation water for agriculture and aquaculture, provides the water supply for industry, energy generation, municipal and civil use, and supports the existence of various ecosystems and wildlife on a large scale. Consequently, demand for its water is very high. In addition, there is dense human settlement in the Huong River plain and coastal area, with the majority of the population living near the poverty line and whose livelihood strongly depends on the river basin's natural and water resources. The seasonal distribution of water resources in the basin is not consistent. Very high discharge in the rainy season causes flooding and inundation whilst low flow in the long dry season often causes a water supply crisis. Potential impacts of climate change and consequent water demand pressure would only exacerbate such crises, increase water pollution and saline intrusion and contribute towards ecological and wildlife degradation.

Phu Vang is a coastal district in the lower part of the Huong River with a diversity of landscapes: mixed low-lying agricultural land and aquaculture ponds cover the river estuary and part of the above-mentioned Tam Giang-Cau Hai lagoon. Phu Vang is among the most vulnerable districts in the province, bearing the burden of untimely pressure from both the ocean (typhoons, storms, sea level rise and saline intrusion) and the river (flood and drought). The low level of local people's awareness and their very limited sources of income, along with their unwillingness or inability to resettle, all contribute to the huge loss of human lives and properties in the case of a large storm or flood. In the 1999 flood, 64 households of Hoa Duan village located in the lagoon were washed out to the sea and hundreds of people died or remain missing.

Since ancient times, Thua Thien Hue Province and the Huong River Basin have been recurrently affected by many types of climate-related disasters such as typhoons, storms, floods, droughts and landslides. Recently, such disasters have increased in both frequency and intensity, causing significant socio-economic turbulence and loss of life, seriously damaging upstream and downstream infrastructure and ecology, impacting on World Heritage Sites and destroying people's livelihoods and properties. Table 1 summarizes the enormous losses in Thua Thien Hue Province caused by recent severe flooding events in October 1983, September 1990 and November 1999.

Table 1: Flood-related losses in Thua Thien Hue Province, Vietnam

No	Losses and Damages	Oct 1983 Flood	Sept 1990 Flood	Nov 1999 Flood
1	**Number of people dead/missing**	30	5	127
2	**Rice paddy** Damaged/inundated subsidiary crop area Damaged industrial crop area Fields swept away/filled up	6,152ha 8,754ha 65ha 30ha	7,066ha 1,994ha 1,577ha 370ha	28,779ha 8,747ha 4,073ha
3	**Infrastructure** Collapsed houses Hospitals Irrigation structures: - Soil swept away - Stone swept away - Concrete Transport networks - Soil - Concrete - Damaged bridges - Electrical cable poles	 1,340 52 1.24 mil. m3 1,050m3 240m3 821,000m3 198m3 54 32	 735 91 1.29 mil.m3 1,265m3 151m3 742,000m3 285m3 55 35	 7,121 119
4	**Other properties** Sunk boats Dead buffalos/cows Dead domestic animals (others)	 915 425 heads 170,000	 270 heads 194,210	 1,645 heads 319,377
Monetary value (with USD approximates)		75 bill. VND (5.6 mill. USD)	120 bill. VND (8 mill. USD)	925 bill. VND (60 mill. USD)

Hue City and the Huong River are both World Heritage Sites and famous tourist destinations, providing income for an increasing number of local people. Protection and adaptation measures for the Huong River system to help address negative changes are very important economically in the context of the above. To better preserve the world heritage and landscapes of Hue City, adjacent areas and the Huong River, it is not appropriate to build dykes along the river or an embankment system around Hue City and the historical sites, so flooding usually spreads across very large areas. In addition, the topography of the Huong River Basin changes rapidly from the upstream mountainous zone to the plains and large lagoon system, with hardly any transition area, resulting in high runoff/flow in the rainy season and extensive floods and inundations downstream.

During the dry season, the prolonged low rainfall causes salinity to intrude far upstream, badly affecting agriculture, lagoon ecology and aquatic resources. The saline intrusion can reach Bach Ho Bridge, more than 10km from the Huong River estuary, where the intake for Hue City's water supply system is located. Moreover, the upstream "slash and burn" cultivation practices and rapid deforestation together with the geographical and meteorological characteristics of the basin are causing more erosion, creating increased risk of land slides and flash floods in the mountainous areas (figure 2).

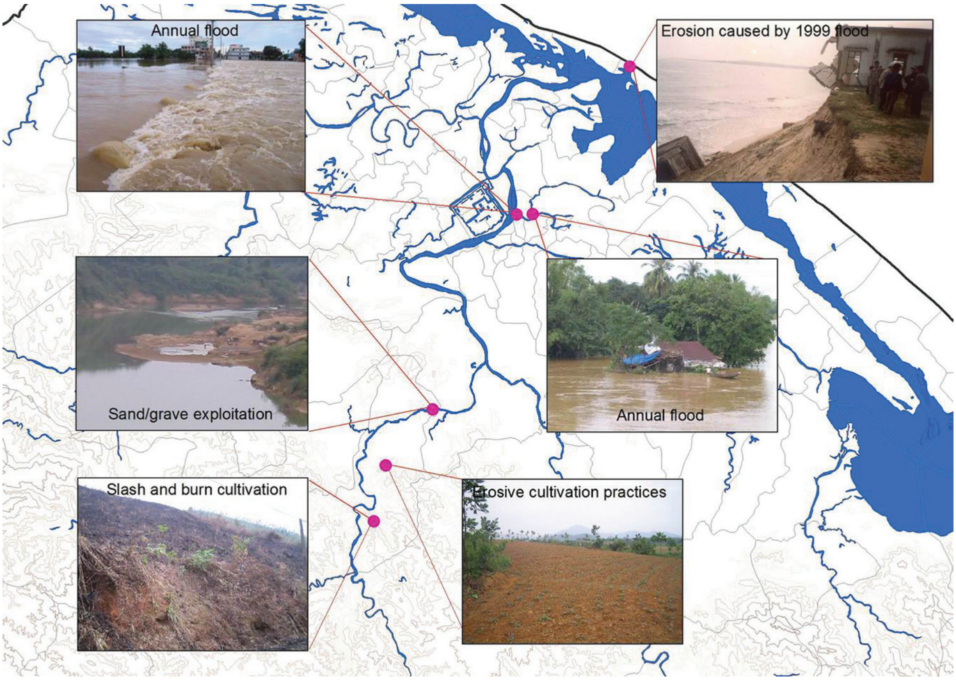


Figure 2: Climate Related Disasters and Environmental Change in Different Parts of the Huong River Basin

2.2 Methodology and activities undertaken

The project combined various stakeholder approaches with water modeling.

The technical tools were selected and deployed by the IMHEN on the basis of the need to provide reliable, scientifically-based results and evidence which could help in convincing local authorities, in raising awareness and knowledge and in designing adaptation measures.

Participatory tools have facilitated the involvement of local stakeholders in all stages of project implementation to ensure (a) the local context and practical usefulness of the project results and (b) that the demands and needs of the most vulnerable people are considered.

The chosen set of participatory management and technical approaches support the effective transition between stages in a project cycle, from research to decision-making and development of adaptation measures.

The following major activities were undertaken:

- Collection and analysis of data on meteorological and hydrological factors and natural conditions, as well as the administrative and socio-economic conditions of the study areas: Thua Thien Hue Province, the Huong River Basin and its coastal zone – Phu Vang district.
- Provision of climate projections and downscaling of regional climate change scenarios to the provincial scale.
- Assessment of the impacts of climate change on water resources by conducting water and hydrological modeling for the Huong River Basin with the help of MIKE 11, MIKE Basin and some other software.
- Collection and analysis of data on livelihoods and vulnerability to climate change and disasters of the poor people in Phu Vang district.
- Development and implementation of the stakeholder action plan (SAP) for the coastal zone, especially Phu Vang district and the most vulnerable commune in the district – Thuan An commune and Chan May–Lang Co – including stakeholder meetings; surveys and semi-structured interviews using PRA tools with different local and external stakeholders; technical workshops with key stakeholders; further guidance and feedback.
- Analysis and synthesis of the results, leading to proposed improvements of adaptation options and policy recommendations.

3. Key results and findings

3.1 Past trends and future climate projections

The project started with a number of studies in order to better understand the historic trends in climate conditions in the study area. In addition, downscaled climate scenarios were developed for the decades up to 2100. Some of the key results of these studies are presented below.

3.1.1 Historic climate trends

In order to understand the historic trends of the climate conditions in Thua Thien Hue, the study analyzed the variability, climatologically average, moving average and trend line of some key climate parameters, including rainfall and temperature. The rainfall was analyzed in 4 different periods of the year: January to March; April to May; June to July; and August to December. Temperature data was taken from January, April, July and October, typical months for the hot season, the rainy season and the two interchanges. The data was collected from three meteorological stations in Hue Province: Hue, A Luoi and Nam Dong stations.

The temperature of all typical months and the mean annual temperature at A Luoi and Nam Dong stations revealed an obvious increasing trend during the studied period (1974 to 2004). Annual rainfall at A Luoi and Nam Dong stations was very high in absolute value (about 3,500mm on average and up to 6,000mm in the peak years), and have significantly increased in the period 1974 to 2004 approximately 800mm and 600mm respectively.

The largest increase in rainfall occurred during the rainy season (August to December), months that were the major contributors to the total annual rainfall. June to July's rainfall at both stations has a noticeably decreasing trend. This indicates a high risk of prolonged drought during the important growth period of major crops as well as a risk of water shortages affecting power generation, especially at a time that the demand for energy is high during the hottest period of the year.

Figures 3 and 4 depict the trends in annual temperature and rainfall changes in the period 1974 to 2004 for different meteorological stations.

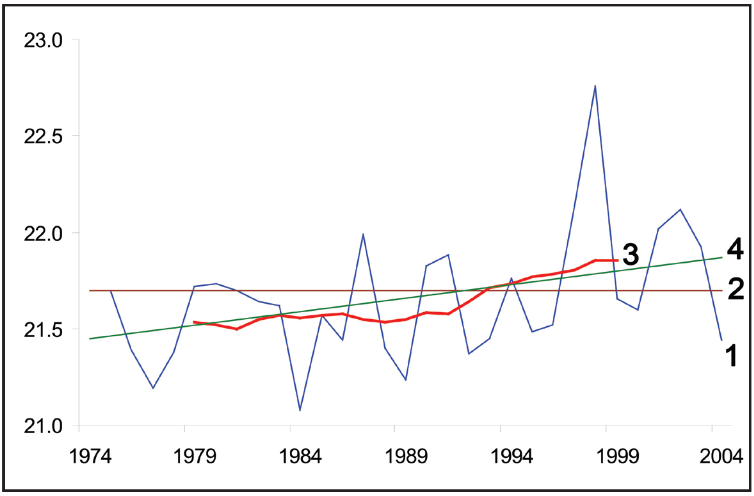


Figure 3: Variability (1), climatological average (2), moving average (time step – 11 years) (3) and linear trend (4) of annual average temperature at Station A.

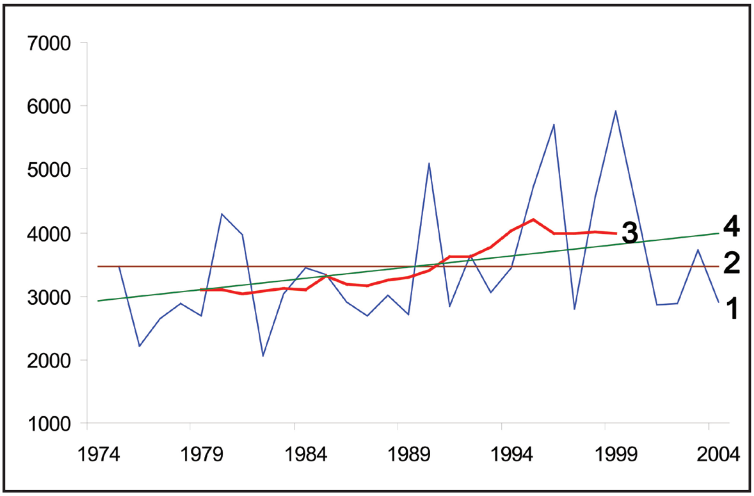


Figure 4: Variability (1), climatological average (2), moving average (time step – 11 years) (3) and linear trend (4) of annual rainfall at Station B.

3.1.2 Future climate change in Thua Thien Hue:

The development of climate scenario data is based on the 'Guidelines on the Use of Scenario Data for Climate Impact and Adaptation Assessment' published by the IPCC. Global and regional (Southeast Asia) scenarios were downscaled into the project area by using MAGICC/SCENGEN software.

The following basic sources of input and boundary data were used for developing the climate scenario:

- Results from Global Circulation Models (GCM) and Ocean-Atmospheric Global Circulation Models (OAGCM);
- The IPCC's global emission scenarios and regional climate change scenarios for Southeast Asia;
- Past trends of observed meteorological data for the last 30 to 40 years in Vietnam and Thua Thien Hue Province;
- Observed sea level data at stations and analysis from the Marine Hydro-Meteorological Center; and
- Experts' opinions, related literature, including influences of regional factors and ENSO on the climate of Vietnam.

Six different emission scenarios (2 High-, 2 Medium- and 2 Low-emission) for Thua Thien Hue were selected. The results of the downscaling represent the changes of rainfall and temperature in the province over the period 2010 to 2100 in comparison to the 1990 baseline for the different emission scenarios. Figure 5 shows an example of the downscaling results of temperature and rainfall for the Huong River Basin for the A2 scenario.

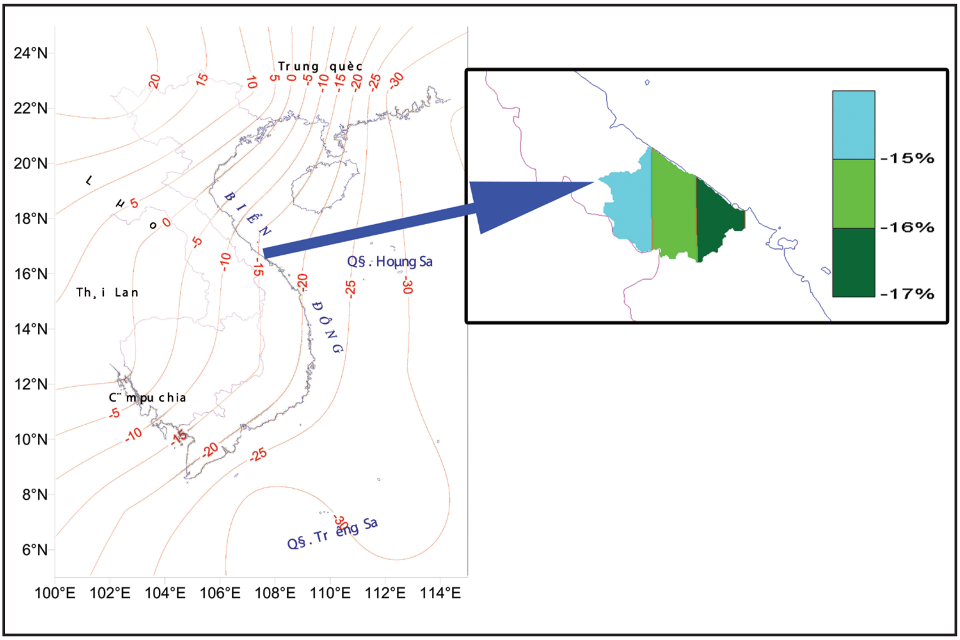


Figure 5: Example of downscaling from regional to provincial projection for Thua Thien Hue for Dec to Feb rainfall in 2100 in comparison with 1990, high emission scenario A2.

According to the model outcomes, the annual mean temperature is expected to increase by 2.5 to 2.6ºC by the end of the 21st century. The increase is more pronounced in January and February (2.6 to 2.7ºC) than in the hotter months of June and July (2.4 to 2.5ºC).

In the case of the high emission scenario (A1FI), the temperature would increase the most: by 3.9ºC on average, and in the March to May period a change of up to 4.7ºC may be experienced (see table 2). Such a high temperature increase may bring very serious consequences for socioeconomic and ecosystem wellbeing, especially for human health, but combined with a projected increase in extreme events (droughts, floods, storms, etc.) it may lead to catastrophe in Thua Thien Hue Province.

Table 2: Projected decadal increase in annual and seasonal temperature (ºC) in TTH from 2010 to 2100, compared with the 1990 baseline for 2 emission scenarios.

Scenario	Period	2010	2020	2030	2040	2050	2060	2070	2080	2090	2100
A1FI	Year	0.2	0.3	0.6	0.9	1.4	2.0	2.6	3.1	3.5	3.9
	Dec-Feb	0.2	0.3	0.6	0.9	1.5	2.1	2.7	3.2	3.7	4.0
	Mar-May	0.2	0.4	0.7	1.1	1.7	2.4	3.1	3.7	4.3	4.7
	Jun-Aug	0.2	0.3	0.6	0.9	1.5	2.1	2.7	3.2	3.7	4.1
	Sep-Nov	0.2	0.3	0.6	0.9	1.4	2.0	2.6	3.2	3.6	4.0
A2	Year	0.2	0.3	0.4	0.6	0.8	1.0	1.2	1.6	2.1	2.6
	Dec-Feb	0.2	0.3	0.4	0.6	0.8	1.0	1.2	1.5	2.0	2.5
	Mar-May	0.2	0.4	0.5	0.7	0.9	1.2	1.4	1.8	2.4	3.0
	Jun-Aug	0.2	0.3	0.4	0.6	0.8	1.0	1.2	1.6	2.1	2.6
	Sep-Nov	0.2	0.3	0.4	0.6	0.8	1.0	1.2	1.5	2.0	2.5

When it comes to annual rainfall, the model results show an estimated increase of about 7% on average. While the dry season of February to May is showing a decrease of 10 to 15%, rainfall is expected to increase significantly during the rainy season (September to November) by 10 to 24%. Rainfall in August – the first month of the rainy season – is expected to increase much less (2.5 to 3%).

In the "worst case" high emission scenario (A1FI), rainfall in the rainy season would increase by 25% whereas the first dry months (December to February) show a decrease of 23% (table 3). The most important aspect revealed is that rainfall in the dry season (December to February and March to May) is likely to decrease, which may cause very severe droughts. If this were to occur, severe drought would be added to the phenomena of flood and typhoon events, adversely impacting the socioeconomic wellbeing and ecosystem functioning in Thua Thien Hue Province.

In general, the results show that the very high rainfall patterns which are concentrated during certain wet months would increase the already high flood risk of the study area, with associated adverse consequences, unless comprehensive and systematic adaptation measures are implemented. Conversely, the dry season is projected to be longer and more severe, which would increase the risk of drought. The longer, more severe lack of rainfall during this period may adversely impact the energy generation capacity of a number of hydropower plants (currently under construction or soon to be built) on the Huong and other rivers of Thua Thien Hue Province. The decreased dry season rainfall may also threaten the municipal water supply of Hue City and agricultural irrigation requirements and cause fresh water shortages for downstream users and ecological systems. The salinization of surface water, groundwater and soil in the coastal areas will be likely to have negative impacts on agriculture, aquaculture and eco-tourism, as well as the unique wetland ecosystems of the Tam Giang-Cau Hai lagoons.

Table 3: Projected decadal change in annual and seasonal rainfall (%) in Thua Thien Hue in the 2010 to 2100 period, compared with the 1990 baseline, for two emission scenarios.

Scenario	Period	2010	2020	2030	2040	2050	2060	2070	2080	2090	2100
A1FI	Year	0.5	0.9	1.5	2.5	4.0	5.7	7.3	8.7	10.0	11.0
	Dec-Feb	-1.0	-2.0	-3.3	-5.4	-8.5	-12.0	-15.4	-18.5	-21.2	-23.4
	Mar-May	0.4	0.8	1.3	3.1	3.4	4.8	6.1	7.4	8.4	9.3
	Jun-Aug	0.7	1.1	2.2	3.6	5.6	8.0	10.3	12.3	14.2	15.6
	Sep-Nov	1.1	2.1	3.5	5.7	8.9	12.7	16.3	19.6	22.4	24.7
A2	Year	0.4	0.9	1.2	1.7	2.2	2.7	3.3	4.2	5.6	7.0
	Dec-Feb	-0.9	-1.8	-2.4	-3.6	-4.6	-5.7	-6.9	-8.9	-11.8	-14.8
	Mar-May	0.4	0.7	1.0	1.4	1.8	2.3	2.8	3.6	4.7	5.9
	Jun-Aug	0.6	1.2	1.6	2.4	3.1	3.8	4.6	6.0	7.9	9.8
	Sep-Nov	1.0	1.9	2.6	3.8	4.9	6.1	7.3	9.4	12.5	15.6

It is evident that both the flood and the drought risks and impacts from projected future climate change are very high for Thua Thien Hue Province.

The sea level rise scenarios of Thua Thien Hue have been estimated by taking average values from Hon Dau Station, representing the coastal zone of north Vietnam; and Vung Tau Station, representing the coastal zone in the south of Vietnam.

The projected sea level rise in Thua Thien Hue would reach approximately 50 to 60cm by 2100, much less than in the northern and southern parts of Vietnam and equally, less than the global projected average. However, uncertainties remain with this relatively modest prognosis, which could be skewed by a number of factors, such as geo-morphological change in the level of the sea floor. Another obstacle to accurate estimation is the discrepancy between the data measurement standards of two periods at the central marine hydromet-stations: before and after the re-unification of South and North Vietnam. Further studies need to be done to obtain more accurate projections of sea level rise in the area.

3.2. Impacts of climate change on the water resources of the Huong River Basin

For the assessment of the potential climate change impacts on water resources, different modeling methods were used, including MIKE11 and MIKEBASIN. The input data that was used included meteorological data (daily maximum and minimum air temperatures, precipitation from 1961 to 2004) and their projections for 2010 to 2100 according to various scenarios. Potential evapo-transpiration (ETo) data was calculated for the baseline year 1990 and for the periods 2020 to 2049 and 2071 to 2100 at A Luoi and Hue stations using the Thornthwaite's formula. Table 4 shows the computational results of monthly average ETo over the selected periods.

Table 4: Monthly potential evapo-transpiration (ETo) of sub-basins in 2100 (mm)

Month	A Luoi	Ta Trach	Hue (LATERAL)	Huu Trach	Bo
I	39.6	41.9	48.3	43.0	41.2
II	45.7	48.6	52.0	48.9	46.9
III	69.0	78.4	76.2	76.6	70.3
IV	76.9	90.9	96.6	90.2	80.4
V	84.6	103.8	126.4	106.1	92.2
VI	85.6	104.7	129.5	107.5	93.5
VII	94.5	112.4	139.5	115.9	102.6
VIII	83.3	99.7	122.7	102.5	90.4
IX	59.1	74.0	90.5	75.5	64.8
X	47.4	53.5	68.1	55.8	51.1
XI	29.4	34.1	47.7	36.4	32.7
XII	25.5	25.5	39.6	28.6	28.1
Total	740.6	867.5	1037.2	887.0	794.0

3.2.1 Climate change impacts on river runoff

For the calculation of runoff flow caused by rainfall in the basin, the Rainfall-runoff (NAM) model was used. When rainfall, rain distribution and rain amount lost by evapo-transpiration and temperature increase changes, the runoff and discharge will also change.

Figure 7 shows the observed and projected monthly flow at Co Bi gauging station for the periods 1977 to 2006, 2020 to 2049 and 2071 to 2100 under the B2 emission scenario. The trend line shows a very small increase in the river flow. Figure 6 further shows the changes in average annual runoff for four different gauging stations for the same periods. As can be seen from this figure, increases in average annual runoff are projected for all stations. For example, the computational results under scenario B2 at Co Bi gauging station are shown in figure 7. For each of the sub-basins, the change in average annual runoff was also calculated (figure 8).

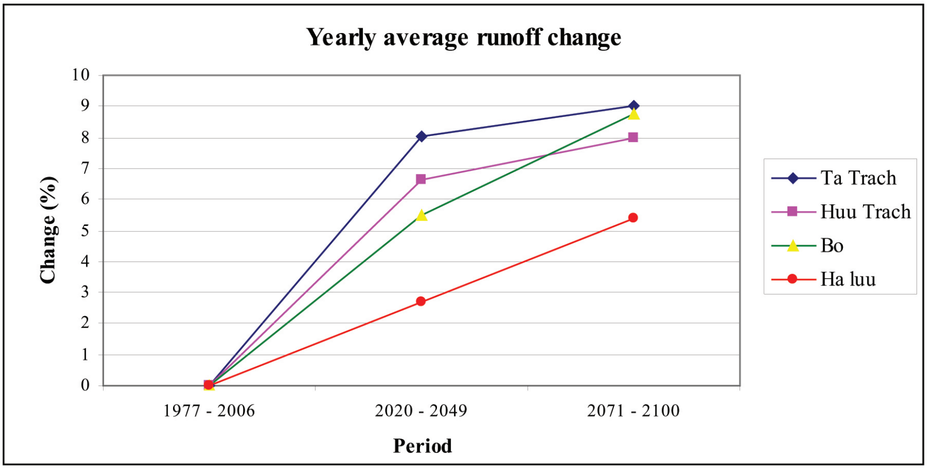


Figure 6: The average change in yearly runoff under scenario B2

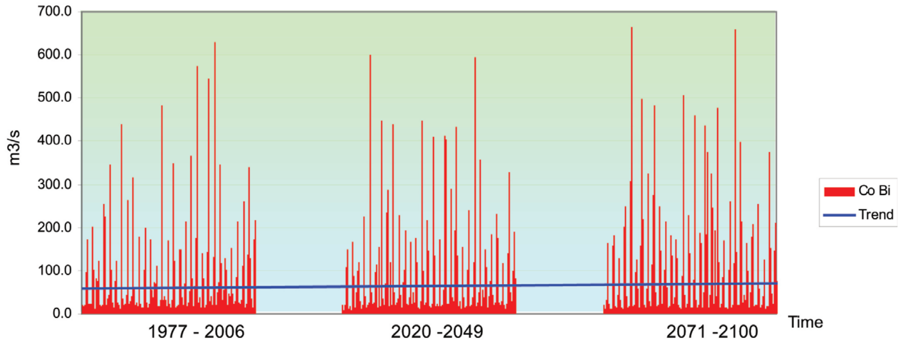


Figure 7: Change in stream flow at Co Bi station in the Huong River Basin under scenario B2

3.2.2 Flood mapping

Based on the MIKE 11 outputs, MIKE 11 GIS was used to interpolate the water levels at all cross-sections in order to construct a grid-based (TIN-based) water surface. The water surface was then automatically compared with a Digital Elevation Model (DEM) to produce and calculate flood depth maps. The flood depth maps were produced for the different emission scenarios and for different areas in the province. Some of the outputs and results from the analysis are presented below.

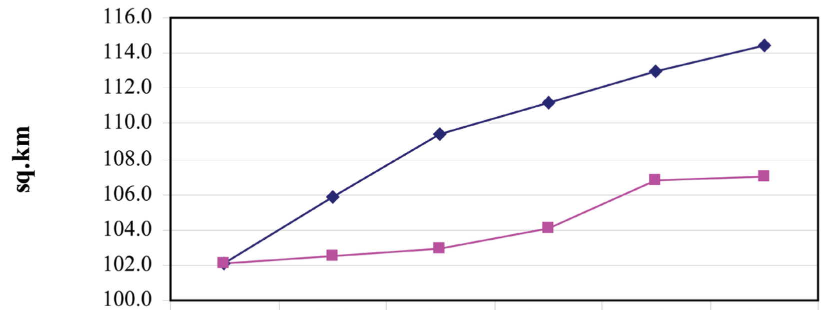
Table 5 shows the projected change of flood depth and flood(ed) areas in Thua Thien Hue province for the A1F1 emission scenario and compares it to the 1999 flood.

Table 5: Flooded area in Thua Thien Hue following scenario A1F1

Characteristics	1999	2030	2050	2070	2090	2100
Max. depth (m)	5.81	5.96	6.08	6.16	6.27	6.44
Area flooded (km²)	388.4	404.5	419.2	439.5	448.8	453.7
Flood(ed) proportion (%)	7.69	8.01	8.29	8.68	8.88	8.98

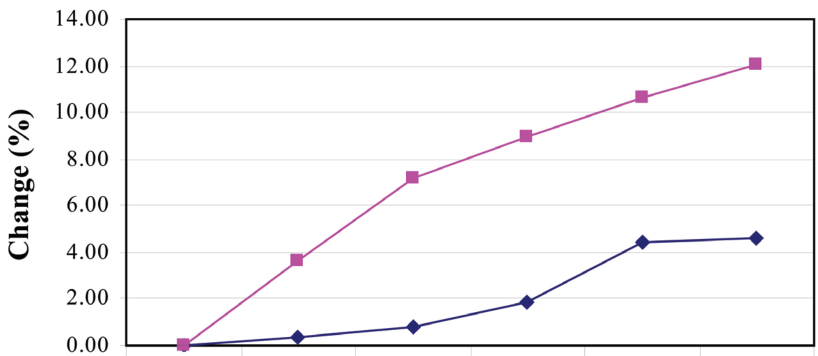
In 1999, with an average depth of 5.81m, the flooded area was 388.4km² accounting for 7.69% of the territory of Thua Thien Hue. By the year 2030, with the depth of flooding at no more than 6m, the flooded area would already be over 400km². By 2050, with the depth of flooding at 6.08m, the inundated area would be 419.2km². In the following decades, the depth of flooding continues to increase until by the year 2100 it is at 6.44m and the associated area of inundation would be up to 453.7km², accounting for 8.98% of the natural area.

Figure 8 below shows two graphs depicting the changes in flooded areas according to the B2 and A1F1 emission scenarios. As can be seen from the diagrams, both emission scenarios will result in an increase of the inundated areas in Phu Vang district. Figure 9 shows an inundation map scenario for 2100.



	Baseline	2030	2050	2070	2090	2100
A1F1	102.1	105.8	109.4	111.2	113.0	114.4
B2	102.1	102.5	103.0	104.1	106.8	107.0

Year



	Baseline	2030	2050	2070	2090	2100
B2	0.00	0.35	0.84	1.87	4.40	4.58
A1F1	0.00	3.62	7.15	8.91	10.64	12.04

Year

Figure 8: Change in the exttent of inundation in Phu Vang district in years corresponding with different scenarios.

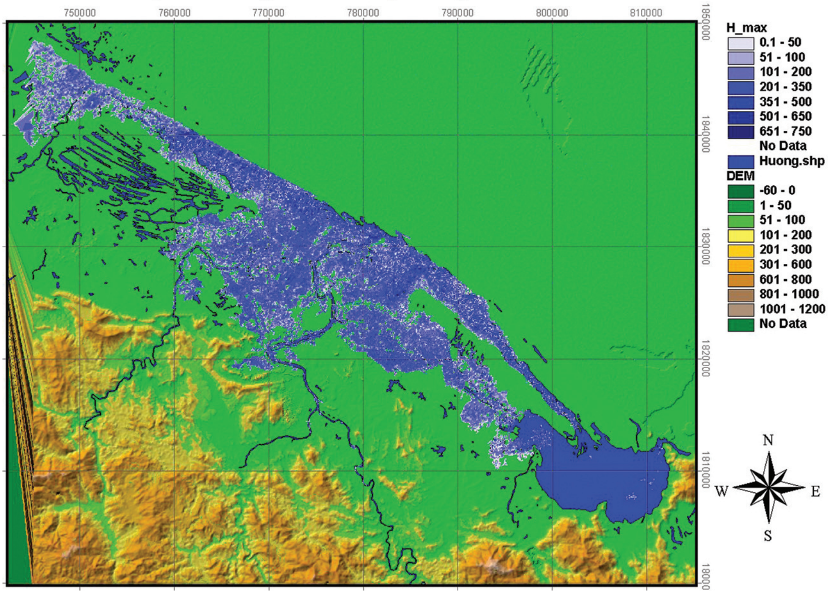


Figure 9: Inundation Map Corresponding with the Year 2100

3.2.3 Impact of climate change on salinity intrusion

The HD and AD modules of MIKE 11 have been used to estimate the salt profile, after proper calibration and verification. Scenarios for salinity intrusion simulation were developed based on the projected change in sea level as described above. The year 2002 was selected as the baseline reference because the observed data from this year was the most complete of that available. Results of salinity intrusion computation for selected scenarios are shown for some cross-sections in the main rivers. The computational results show that there will be an increase in salt concentration as time passes in correlation with sea level rise. Table 6 shows the computation results of the increase in salt concentration in one location along the Huong River.

Table 6: Salt concentration change at Pho Nam and Phu Cam (scenario A1F1)

Cross-section	Parameter	2002	2030	2050	2070	2090	2100
Phu Cam	Average salt concentration (%)	2	2.1	2.17	2.33	2.41	2.47
	Percentage (%)	0	5	8.5	16.5	20.5	23.5
Pho Nam	Average salt concentration (%)	2.45	2.65	2.84	3.05	3.24	3.39
	Percentage (%)	0.00	8.16	15.92	24.49	32.24	38.37

The results of salinity intrusion as calculated by the model clearly show that due to the effect of sea level rise and water shortage, increase in use during the dry seasons, the salinity of most rivers in the Huong River system will increase considerably. Therefore, further anti-saline measures will be required, notwithstanding existing infrastructure developments.

3.3 Climate change impacts on other sectors in Thua Thien Hue Province and local impacts at the district and commune level

Apart from assessing the impacts of climate change on water resources, the project has also looked into the impacts of climate change on other sectors in Thua Thien Hue Province and Phu Vang district. In addition, more detailed assessments have been carried out in order to better understand the potential impacts of climate change on two specific areas in the province: Phu Vang District and Chan May–Lang Co Special Economic Industrial Zones.

The impact assessments were largely based on interviews and workshops/ meetings with local and external stakeholders at provincial, district and commune levels, using UNEP and IPCC methodology, as well as participatory approaches. The assessment was done for all relevant sectors, natural and water resources (as above), biodiversity, agriculture, aquaculture, forestry, industry and energy, transport and construction, culture and sport, tourism, trade and services, with an emphasis on the highly important coastal zone of Thua Thien Hue Province.

Analyses of data and information on the impacts of and vulnerability to climate change for the poor people in Phu Vang district and in one particularly vulnerable commune –Thuan An – were also conducted. The information and data was obtained through a variety of participatory methods including stakeholder analysis, participatory rural appraisal, semi-structured interviews, focus group discussions, etc. A brief summary including some representative examples of the climate change impacts is presented here. The full details are available in separate technical reports.

3.3.1 Climate change impacts on agriculture

- Most of the current rice paddies could be flooded during wet season and salinity intrusion could take place during the dry season, especially in areas of low elevation and land near the river/ lagoon, leading to a decrease in food yield and a threat to food security.
- Some riparian protective forests could become flooded and saline intrusion could lead to the disappearance of some rare and valuable genetic resources.
- Rice plants, short-term and long-term planted trees and long-term, newly developed industrial trees such as rubber, may suffer more damage when the frequency of natural disasters increases. The crop pattern, seasons and even productivity could also expect to be affected by climate change.
- An increase in animal, livestock and crop diseases and infections through the spread and introduction of new pests and pathogens and crop diseases may take place. More pesticides and chemicals might be used to combat this, increasing the danger and risk of pollution.
- An increase of erosion and soil degradation, leading to lower crop productivity may occur.

3.3.2 Impacts on natural fisheries and aquaculture

- Disruption of the fisheries due to changes in the seasons for aquatic farming and shortening the lifetime of certain farming tools.
- Changes in the currents at some river mouths, affecting the itinerary of fishing boats and other ships and fish migration/spawning routes.
- Changes in the natural environment, leading to changes of biodiversity, the behavior of aquatic animals and changes of genetic diversity of aquatic species.
- When temperatures exceed 40ºC, the growth of animals in aquaculture ponds is slowed, and they may even die, affecting farm productivity. In addition, bacteria and fungi multiply more profusely, resulting in epidemics and eutrophification of farming ponds in the lagoon.
- Infrastructure (e.g. electricity, roads, levees and canals inside the fields) serving the aquaculture and fishery sectors will degrade more quickly.

3.3.3 Impacts on biodiversity

Climate change and sea level rise may increase the salinity of the brackish lagoon water, adversely affecting the ecosystems of the Tam Giang-Cau Hai wetland and current conservation efforts aimed at protecting areas such as the unique bird habitat of O Lau and the mangrove forest in Ru Cha. Many endangered species would be placed at high risk of extinction. The projected extension of the lagoon and frequently flooded area would alter the shoreline and estuary and destroy the large mangrove forest and habitat of many species, including those that are endangered.

The solutions proposed and implemented (weir, dam, etc.) to address salinization due to sea level rise could affect migratory animals and micro organisms, including the migration for reproduction of “native” species such as the flower eel, ebony eel and spotted sardine. This could also restrict the transition and interaction between the freshwater, brackish-water and marine ecosystems, potentially limiting the adaptation capacity of wildlife, domestic animals and crops.

A rise in sea temperature could also affect coastal and marine ecosystems such as coral reefs.

3.3.4 Impacts on the coastal zone

The coastal zone accounts for 30% of the area and more than 30% of the human population of Thua Thien Hue Province.

Climate change impacts on the coastal zone in the province include:

- The enlarging of wetland and flooded areas in Tam Giang-Cau Hai lagoon will decrease the land of the delta and coastal plain, increasing the downstream effects of floods on the Huong River.
- The flooding of terrestrial ecosystems may result in the loss of mangrove forest.
- Eroded seashore, decreased land for cultivation and dwindling residential areas will adversely affect local incomes and livelihoods, including those of fishermen, farmers, industrial workers and enterprises around the lagoon and downstream of the Huong River.
- Threats to infrastructure and transportation networks (especially sea dyke and coastal highways), irrigation and waterworks which were designed and constructed without consideration of sea level rise; will indirectly increase public and private sector expenditure on construction and protection of infrastructure in lowland areas and seaports.
- Increased pollution of the aquatic environment in the coastal zone and saline intrusion in the Huong River, would lead to (fresh)water scarcity.
- There could be an indirect contribution to increased unsustainable exploitation of natural resources, and associated disputes and conflicts regarding natural resource use in the basin.

3.3.5 Impacts on tourism

Tourism is prominent in Thua Thien Hue Province due to its natural and cultural features. However, climate change may harm the economic benefits resulting from the culture, sport, tourism, trade and service sectors.

Sea level rise may inundate coastal beaches of the province, some of which could disappear, while others will move inland reducing access to the seaside. Sea level rise may also damage the cultural and historical heritage, protected areas and related infrastructure of the ancient city of Hue and the province.

3.3.6 Impacts on the Chan May–Lang Co Special Economic Industrial Zones

Located along the southern part of the Thua Thien Hue coastline, the Chan May–Lang Co Special Economic Industrial Zones (SEIZs) serve as the centre of the province’s economy and tourism sector. However, the SEIZs have recently been faced with increased storms and floods events and sea level rise.

Table 7: Potential severity of disasters and related impacts in Chan May–Lang Co SEIZs

Subject		Sea level rise	Pre. Change	Typhoon	River flow	Landslide	River bank, sea dyke erosion	Increase in temperature	Flash	Drought and salinity intrusion
Land use planning	Harbour	+++	+	+++	-	++	-	-	-	+
	Coastal tourism area	+++	++	+++	+	-	++	-	-	-
	Economic Trade area	+	++	+++	-	++	-	-	-	-
	Urban area	++	++	+++	++	-	++	-	-	-
	Lang Co town	++	++	+++	++	-	++	-	-	++
	Son Tra peninsula	+++	-	+++	-	+	-	+++	-	+
	Voi stream	-	++	+	++	++	-	-	++	++
	Hoi Dua, Hoi Mit	-	++	++	+++	++	-	-	+++	++
	Bu Lu Man-grove forest	+++	-	++	-	-	-	+++	-	++
	Chuoi flood plain	+++	-	+++	-	+	-	-	-	++

+++: Strong impact
++ : Medium impact
+ :Low impact
- : Non-impact

According to the socioeconomic development plan and vision, by the year 2020 the SEIZs will be the international trading and transport hub of central Vietnam. Chan May–Lang Co will have a special duty-free trade area of 962ha and an industrial park of 560ha, while Chan May Port will be developed with a total land and water area of 684ha. Chan May Town will consist of 1650ha and in the tourist area near Lang Co-Canh Duong-Lap An lagoon will encompass 3700ha.

In recent years, the Chan May–Lang Co area has felt the effects of many natural disasters such as floods, flash floods, whirlwinds, landslides, and river bank and coastal erosion. In particular several strong typhoons occurred, with a wind scale of 9 to12 and storm surges of up to 1.5m in typhoon No. 6 in 2006 and 1.7m in typhoon CECIL in 1985 which caused substantial damage.

If potential climate change impacts are not adequately considered as early as possible, much of the above mentioned undertakings planned for the SEIZs will be at increasing risk, which may negatively impact economic productivity.

During this project, interviews and surveys were conducted and a number of meetings with a "CCP expert group" were carried out as part of efforts to integrate climate change adaptation into the planning process and construction of the SEIZs, and to raise the awareness of private and public sector actors in the area.

The SEIZs' management board has acknowledged the potential challenges that climate change and the associated increase in disasters may bring, and this was facilitated by the preparation of the vulnerability and disaster risk maps produced by the CCP group.

Expert assessment of the impacts of disasters on different zones and sectors in Chan May–Lang Co area reveal that the main events likely to arise are typhoons, sea level rise, floods, droughts and salinity intrusion. The agriculture, aquaculture forestry, irrigation, water resources and water supply sectors are those likely to bear the brunt of any increase in disasters. Table 7 highlights the potential severity of these impacts.

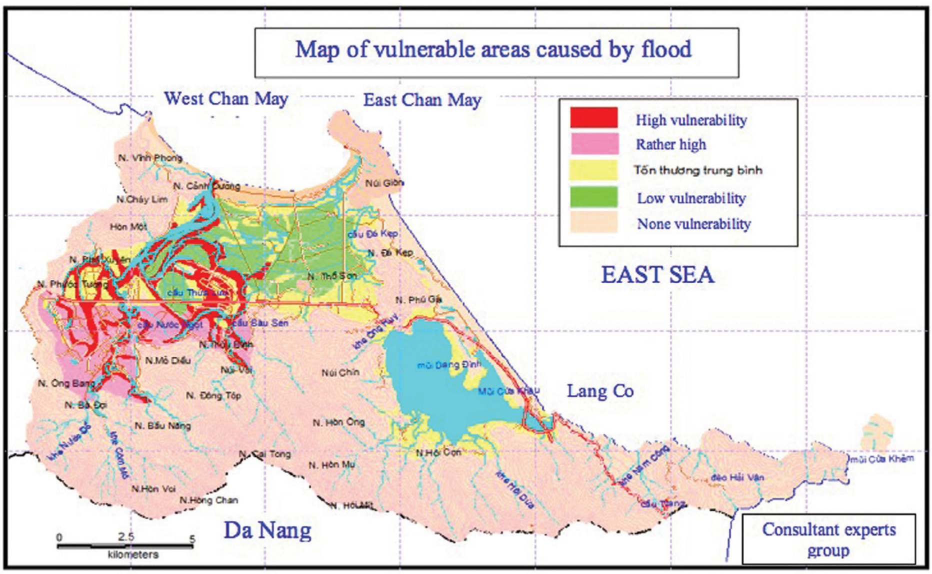


Figure 10: Flood vulnerability map for Chan May–Lang Co SEIZs

3.3.7 Climate change and disasters in Phu Vang district and Thuan An commune

With agriculture, fisheries and aquaculture being the mainstay of the local economy, Phu Vang district faces serious challenges from disaster events and the potential effects of climate change. Results from the stakeholder consultation process as well as the results from the participatory rural appraisal and other surveys indicate that the types of disasters and climate change impacts witnessed in the district are similar to those of other coastal and lagoon areas of Thua Thien Hue Province. However, a number of findings specific to Phu Vang district were exposed.

The most threatening disasters as perceived by local people are floods and storm events, which could trigger a sudden and strong change of the sand bars and lagoon basement, the so-called "lagoon gate opening" effect. Such an event did occur in Hoa Duan commune in 1999, where 64 households were washed out to sea and hundreds of people died or went missing.

Coastal hydrodynamic change can lead to the destruction of important infrastructure like dykes as well as houses. Very deep erosion (up to hundreds of meters) may be seen in one place and heavy sedimentation in another. Engineered structures, such as the H-form concrete bars built by the French during colonial times at 30m from the shoreline, could help prevent some erosion. Additional studies should be done to better understand this hydrodynamic process and identify proper solutions.

Indigenous knowledge has proved very useful to local communities in predicting and coping with disasters but in recent years it has become less effective as weather and climatic patterns shift.

The flooded area is likely to become more extensive due to climate change, with the effects of a November 1999 catastrophic event (when 36.4% of the area flooded) potentially reaching up to 40.4% if a similar event were to occur in the future (see table 8).

Calculations of projected flooding in Phu Vang district are as follows:

Table 8: Projected area and proportion of land flooded in Phu Vang District according to scenario A1F1

	1999	2030	2050	2070	2090	2100
Depth of flood (m)	5.81	5.96	6.08	6.16	6.27	6.44
Area of flood (m)	102.1	105.8	109.4	111.2	113.0	114.4
Proportion of flooded area (%)	36.4	37.2	39.0	39.2	40.3	40.8

Drought and salinity intrusion are also expected to increase in Phu Vang based on the climate change scenarios. By the end of the century, salinity in the Huong River mouth could increase by 20 to 40%, and saline intrusion may penetrate 2 to 3km further upstream than at present, if proper counter measures are not undertaken.

Thuan An town in Phu Vang district is located on the depressed estuary plain of the Huong River Basin. Part of the lagoon area houses of Thuan An's villages, while another seven are near Tam Giang-Cau Hai lagoon and five are close to the sea (figure 11).

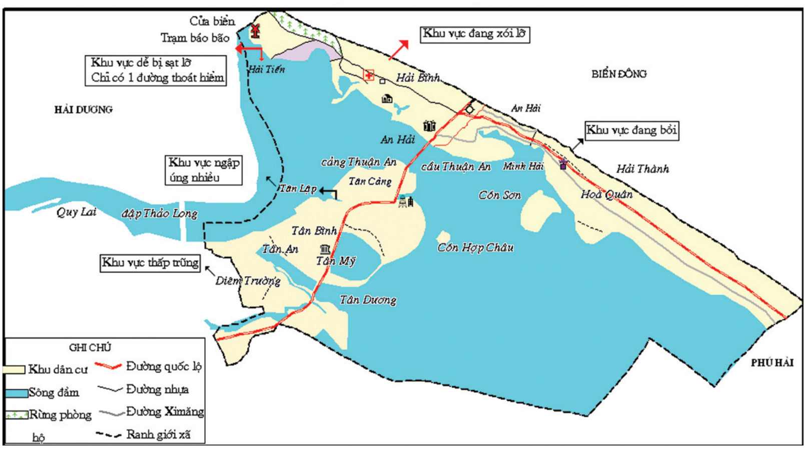


Figure 11: Map of Thuan An Commune

A number of interviews, group discussions and workshops were carried out in Thuan An to help identify the real-life local context of disasters and climate change impacts, the socioeconomic and environmental situation, autonomous adaptive capacity and relevant indigenous knowledge and local customs. This has resulted in a number of area specific outputs, including a detailed vulnerability map (see figure 12) and some village specific adaptation measures. Apart from collecting information about vulnerable areas, the group discussions have also greatly increased the awareness of local people about the potential threats of climate change.

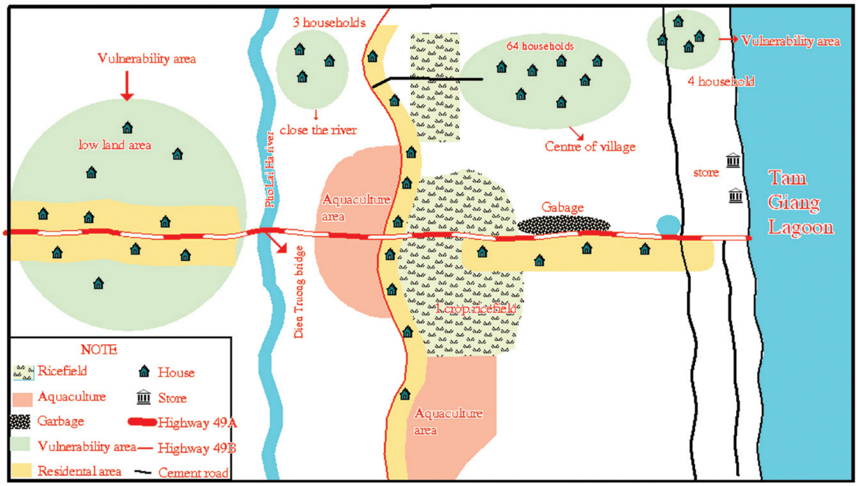


Figure 12: Dien Truong Village’s Vulnerability Map, Thuan An Town

4. Working towards an adaptation policy for Thua Thien Hue province

The Integrated Coastal Zone Management (ICZM) strategy for Thua Thien Hue Province reflects the willingness and commitment of the provincial authorities and people to carefully balance interests with respect to the protection and the use of coastal resources and environment for the sustainable development of the coastal zone.

The ICZM strategy document was promulgated at the national level in 2003. The strategy of the ICZM agrees with the strategy of adaptation to climate change in the approach, methods of implementation and objectives of environment protection for sustainable development. As such, the document could serve as an appropriate basis for implementing climate change policies and measures at the provincial level.

At this moment, however, the process of preparing the ICZM strategy has not yet considered the changes in climate as well as their impacts on natural conditions of the study area. Therefore, the NCAP project, in close consultation with relevant provincial stakeholders, took the initiative to integrate some climate change adaptation proposals into important sections of the ICZM strategy. The following proposals have been made for inclusion into the ICZM Strategy:

- Raising management capacity for the ICZM strategy in areas likely to be most affected by climate change. Raising awareness and knowledge among community members, local government authorities and policy makers on future climate-related disasters and adaptive measures for the ICZM to respond to climate change.
- Re-development of the coastal zone management framework protocol and action plan in the administrative system of Thua Thien Hue focused towards sustainable development, shared benefits and adaptation to climate change.
- Re-recognition of the areas, fields and communities most vulnerable to climate change impacts and identification of effective measures to maintain sustainable development in these specific zones.

- Re-assessment of the carrying capacity of the coastal zone and lagoons and potential adaptive capacity of relevant sectors (agriculture, aquaculture, tourism and industrial development) in the coastal zone.

5. Lessons learned and strategic recommendations

5.1 Lessons learned

In recent decades Thua Thien Hue Province has experienced an increase in climate change-related events: significant increases in temperature, wet season rainfall, flooding and inundation have been noted. Consequently, incidences of drought, river bank and coastal erosion, and salinity intrusion have become more severe. Thanks to project activities supported by the NCAP, policy makers and communities in Thua Thien Hue have become more aware of the extent that climate change will have on all sectors of society and in particular on agricultural production and in coastal areas. In the course of the project, the following lessons have been learned.

5.1.1 Take advantage of local resources and existing knowledge

Optimal and creative use of all available local resources and consideration of all relevant past and ongoing studies and projects was a priority focus of this project. Within the extended project time-frame, IMHEN as the implementing party was able to produce a variety of outputs on a limited budget: a climate change impact assessment for water resources at river basin scale; downscaled climate change scenarios for a limited area; climate projections and hydrological modeling; participatory studies; local adaptive capacity assessments; and adaptation measure analysis at the provincial, district and town levels. All of the initial targets were reached to varying extents.

The above results were achieved in part thanks to the proper mobilization of local resources, including information and data, technical, financial and human capacity and collaboration with other projects, assessments and activities and the sharing of the results of such. This last point will be described further below.

5.1.2 Cooperate to reduce costs and avoid duplication of effort

Close collaboration with relevant development projects working in the same area or sector, or with similar objectives, should be encouraged to avoid the duplication of effort and to maximize the sharing of information, technical advice, reports, networks of contacts, and financial and human resources.

In the first phase of this project, two meetings were organized with representatives of different organizations and initiatives in Thua Thien Hue Province and especially in Phu Vang district (including IMOLA, ICZM, FAO, CECI, PVC, Kyoto University, and ABD) where the participants shared information and experiences, contacts and networks. All the participants acknowledged the importance of such a dialogue and mechanism for collaboration. However, it was also recognized that most of the projects still have weak links with one another and have no budget allocations to support coordination. Moreover, there are many constraints limiting effective collaboration, such as the lack of a dedicated platform for cooperation and communication and the bureaucracy of some local institutions, among others.

In this regard, the establishment of a special unit for coordination of relevant activities with small but secure budget allocation, possibly independent from the local government, would be highly beneficial. At present, such an inter-agency coordination body does not exist, so it is recommended to encourage all donors and investors to allocate a certain amount of project budgets to a "collaborative fund" for this important and potentially very cost effective mechanism.

5.1.3 Use a combination of top-down and bottom-up participatory approaches

Local communities and the rural poor are often the most vulnerable sectors of society who will feel earliest and bear the full brunt of the negative impacts of climate change. As these groups are also among the intended project beneficiaries, they need to be involved in the process of adaptation at all stages, from initial project development to the monitoring and evaluation of the project outputs. Therefore, a bottom-up approach is essential in designing practical adaptive measures to match the specifics of the local context and in developing small-scale adaptation and other projects.

The bottom-up approach may not be entirely sufficient, however, for a more strategic project aimed at influencing policy-making and implementation. If this is the case, a combined approach would be the most effective.

5.1.4 Translate scientific study results into a language understandable by the end-users

One of the most difficult but important tasks in a project such as this is to reformulate scientific conclusions into a language and format that is easily understood by the different target groups: provincial leaders and policy makers, private and public sector managers, local authorities and local communities, and poor people.

Rural inhabitants and the urban poor may not speak the same language as technical experts and scientists, and often have little free time or interest in complicated scientific issues, so all project and study results should be simplified and presented in a locally coherent way.

Conversely, policy makers and national authorities require concrete and reliable evidence – figures, data and facts that should be related to or spark their interest (political, economic or other), with an emphasis on shorter term decisions and plans as abstract ideas or long term challenges do not always catch these stakeholders' attention.

The potential impacts of climate change over the long term are often ignored or misunderstood by local communities and state authorities. Some of these actors may also be already (intentionally or not) undertaking what could be considered as autonomous adaptation measures. The task of the experts and project teams is to raise awareness and understanding, which may lead to concrete positive actions.

5.1.5 Use indigenous knowledge and expert opinion wisely

Local people know much better than others their needs and fears, the location of areas most vulnerable to climate change and disasters and economic or livelihood opportunities in and around their communities, but they can often benefit from the technical support and objective view provided by outside experts.

Confusion regarding the concept of climate change, related information and relevant countermeasures – for example the difference between mitigation and adaptation – can be common place, so some clarification and capacity building is usually needed.

During project implementation, many new ideas and findings may arise while working with local people or governmental bodies. It is often the case that project experts have not considered all aspects of a project, especially if prior consultations were not undertaken with local communities. So while managers may have a good idea of the overall project objectives, creative and innovative solutions may be provided by project stakeholders, ideas which could even change the implementation direction or intended outputs. In such a case, the purpose and overall objectives of the project can remain but a reorientation of certain specific objectives or outputs may be useful to better fit the practical reality.

5.1.6 Think globally, act locally

Regional, national and local adaptation to climate change should be linked to the global context in terms of knowledge and information availability, technology transfer and financial support from, and experience sharing with, the international community. Such cooperation can bring benefits and opportunities to local people, as is the case with the NCAP project for Thua Thien Hue Province, Vietnam.

However, adaptation to climate change needs to also begin with, and focus on, the everyday actions of individuals to encourage changes in awareness, attitudes and behavior. In order to help achieve this, near-term concrete targets to adapt to climate variability and disasters should be promoted and local development challenges may need to be addressed.

5.2 Strategic recommendations

Despite the emphasis given to achieving accelerated economic growth, the Government of Vietnam acknowledges that controlling and reducing the consequences of climate change and disasters are also key priorities. State and industry responses to climate change would have to be carried out systematically and be consistent with the policies and plans of various sectors and regions, in particular with the national economic development plan as well as that of a province such as Thua Thien Hue.

The results of this project should be used in mainstreaming climate change adaptation into the provincial socioeconomic development plan, as well as into the Thua Thien Hue ICZM action plan, which should be revised in 2009. A number of initial difficulties were encountered by the project team while trying to propose the integration of climate change adaptation considerations into policy-making mechanisms and administrative processes. Fortunately, with the increasing awareness of the Government of Vietnam regarding potential climate change impacts and risks and the ongoing process of preparation of the National Target Program to Respond to Climate Change (NTP), which is also led by the IMHEN and MONRE, the integration process will be implemented at the provincial level very soon.

5.3 Specific recommendations for Thua Thien Hue Province

The following are specific recommendations for the most vulnerable sectors and areas – agriculture, water resources and coastal zones – of Thua Thien Hue Province:

5.3.1 Adaptation options for agriculture and rural development

Promote appropriate changes in crop patterns and domestic livestock in high risk zones, convert low-productivity rice areas into aquaculture; assess and familiarize with new crop seasons, implement suitable technical practices for agriculture.

Use hardy crop varieties that can overcome excess water, drought and extreme weather conditions. Reorientate the existing 5 million ha forestation program towards an upstream protected forest, the coastal green belt and mangrove forests.

5.3.2 Adaptation options for water resource management and disaster prevention

- Develop and implement an integrated water resource management plan for the province considering climate change impacts and increasing water demand.
- Improve the water regulation and flood protection systems, dykes, irrigation infrastructure, dams and reservoirs in order to protect and better exploit cultivated areas.
- Develop and improve the disaster management and search and rescue plan for vulnerable locations.

5.3.4 Adaptation options for coastal and lagoon areas

An adaptation framework should be established for the coastal zone and lagoon area which should have the purpose of: preventing loss of life and property, avoiding development in disaster-prone areas and ensuring that critical coastal ecosystems, such as wetlands and coral reefs, are protected and remain functional. Specific adaptation options could include:

- Good practical implementation of the ICZM strategy with consideration of climate change and its potential impacts on the sustainable development of the coastal zone.
- Protection for populated areas: construction of sea dykes is the measure of choice to prevent erosion in densely populated coastal areas. However, sea dykes do not resolve the underlying cause of erosion, and they can promote the offshore movement of beach sediments. The dykes are also costly to build and maintain and they will need to be extended as the sea level rises. Seawalls should be used only to protect valuable property and buildings that cannot be relocated. For new infrastructure development, the use of setbacks and relocation could be considered.
- Land use policies should encourage settlements away from low-lying and high-risk coastal areas through, for example, the use of coastal hazard mapping.
- Prevention of erosion: depending on the infrastructure and population density, adaptation options to prevent coastal erosion include (i) no response, where there is little habitation or infrastructure; (ii) accommodation, where property is replaced as it is damaged; and (iii) shoreline protection, in areas with large populations and significant infrastructure. In low land areas, where it is essential to retain over-wash sediments and other coastal vegetation to promote shoreline accretion, closing or narrowing selected passages between the lagoon and the ocean, and the strategic use of groynes to help minimize the transfer of sediments from the ocean side to the lagoons could be useful. Sea dykes, however, should be used only in key locations, such as along the edges of important waterways, as they tend to cause downstream erosion and require continual maintenance. In less developed areas the use of setbacks to control future development, beach nourishment and relocation of infrastructure might be preferable.
- Protection against inundation: in areas with little infrastructure, the costs of protection are likely to be prohibitive, and relocation or modification of structures to accommodate surface flooding should be considered. In more populated areas, strategies to allow over-wash sediment to naturally increase the elevation of the coastal zone may help offset the impacts of inundation. Where land ownership disputes are not an issue, new structures should be set back from the shoreline and elevated to allow for periodic flooding.
- Population relocation: if all other measures fail, population relocation may need to be considered. While some communities may opt to move on their own, population relocation would pose immense social and political risks for the Thua Thien Hue authorities, as nearly all inhabitable land is under some form of customary ownership.

Yemen Country Report

Anwar Noaman, Fahmi Binshbrag, Abdulla Noaman, Mansour Hadeira, Alkhatib Al Kebsi, Saif Ali Othman, Chris Swartz, Bill Dougherty, and Amanda Fencl

1 Introduction

The project carried out in Yemen under the Netherlands' Climate Assistance Program (NCAP) explored the linkages between water scarcity and climate change. While there were numerous activities and outputs of the project spread over the period 2006 to 2008, efforts focused on the overriding goals of (1) achieving a better understanding of both the level of vulnerability of rural/urban communities to future changes in local climatic regimes; and (2) identifying types of adaptation activities that would build resilience against increasing water scarcity.

Yemen is an arid Middle Eastern country, occupying an area of 527,970km^2 at the south of the Arabian Peninsula. It is bordered to the north by Saudi Arabia, to the east by Oman, and to the south and west by its 1,900km coastline along the Gulf of Aden and the Red Sea. With an annual population growth rate of about 3.5% – one of the highest in the world – Yemen's population is putting increasing pressures on its limited water resources and straining the ability of the government to provide vital social services. As of 2000, Yemenis numbered approximately 18.3 million, an increase of nearly 4 million over the course of the previous six years. During the same time, poverty increased nearly threefold, particularly in rural areas, where three quarters of Yemenis live. Yemen is burdened with low human and economic development, serious environmental challenges, and a high degree of vulnerability to current and future climatic variability and change. It is widely acknowledged within government policy dialogues that Yemen's major environmental resource problem is water scarcity, a situation prone to exacerbation under climate change. According to the country's First National Communications to the UN Framework Convention on Climate Change (UNFCCC), temperature across the country is expected to rise, while precipitation is expected to decrease, leading to increased pressures on the country's delicate balancing act between water resources and water consumption.

Rainfall varies widely, depending on its five ecological zones: hot and humid coastal plains, temperate highlands, high plateaus and uplands, desert interior, and islands in the Red Sea. Annual rainfall varies from less than 50mm in the coastal plains, rising with the topography to between 500 and 800mm/year in the western highlands, and dropping again to below 50mm/year in the desert interior zone. The rains come primarily in spring and summer, and are determined by two main mechanisms: the Red Sea Convergence and the Inter Tropical Convergence Zone. Temperature depends primarily on elevation, and in the coastal areas, is determined by distance from the Red Sea and Indian Ocean. Average annual temperatures range from less than 12°C in the Highlands (with occasional freezing) to about 30°C in the coastal plains.

Historically, as per capita availability is falling steadily with growing population, scarce water resources have become increasingly precious. In 1955, Yemen's per capita water availability was about 1,100m^3. By 1990, it had fallen to less than half of this level, about 460 m^3/person/year, and is projected to drop to 150 m^3/person/year by 2025 under business-as-usual scenarios of increased demand – to say nothing of future climate change-related impacts. Whereas surface water is largely seasonal and unreliable, groundwater is being extracted in extreme excess of natural recharge levels.

Yemen continues to make development strides, yet profound poverty and other challenges persist. The 1998 Household Budget Survey showed that about 18% of the population lived under the food poverty line, with about 42% incapable of meeting basic food and nonfood requirements. Unfortunately, these percentages remain largely unchanged today and reflect the entrenchment of poverty conditions among approximately 7 million people. Moreover, other factors such as adult literacy (at 54% of the general population over 15 years of age; significantly higher for women) and GDP per capita (at US$760/year) combine to place Yemen near the bottom of the Human Development Index in 2007.

The rest of this report describes the processes, activities, results, and lessons learned from the Yemen NCAP project. The next section describes the rationale and key objectives of the project. Section 3 presents key results and finding, section 4 presents lessons learned, and an annex is included that provides an overview of the key outputs of the project.

2 Rationale and Objectives

Of the many sectors that are vulnerable to climate change in Yemen, water resources are considered the most vulnerable, with potentially grave environmental and social effects, compounded by the country's poverty alleviation challenges. The sustainable exploitation of Yemen's water resources are a high priority under national environmental and agricultural policies, as well as multilateral environmental agreements to which it has signed on (i.e., the UNFCCC, UNCCD and UNCBD).

It is important to note that the focus on water scarcity benefited from and built upon the significant level of capacity enabled by the earlier Netherlands Climate Change Studies Assistance Program (NCCSAP) which ran from 1996 to 2000. Dutch water specialists provided technical backstopping support for the preparation of the vulnerability chapter of the country's First National Communication under the UNFCCC. Support was also provided in the analysis of climate change impacts on agricultural activities.

While presently engaged in a range of national efforts to manage its scarce water resources under known climatic conditions, Yemen's vulnerability to increased climatic variability and future climate change threatens and may ultimately thwart such efforts. Indeed, addressing poverty through improved agricultural production is among Yemen's development objectives. Production is consistently quite low, however, due in part to the vulnerability of rain-fed agriculture to rainfall variability and prolonged drought. Layered on top of the prevailing conditions of poverty, environmental and climatic factors create a number of pressing challenges for Yemen.

Desertification, brought on by recurrent droughts and human land-use pressures, has consumed significant land area and continues to threaten precious arable land resources. Today, arable land constitutes roughly 3% of Yemen's land area, with agriculture contributing 20% of Yemen's GDP and supporting 53% of employment, with traditional subsistence agriculture dominating production. Adaptation-related activities that build upon existing national processes forge new linkages where possible – and break new ground where needed – have the potential to reduce the vulnerability of water resources to climate change. The research and implementation processes of the NCAP project offered an opportunity to better understand linkages between climate change and water scarcity.

The primary aim of the NCAP project was to identify and mainstream priority adaptation activities that would build resilience against increasing water scarcity among vulnerable communities, sectors, and ecosystems in three representative areas. Within this overarching goal, there were four major objectives for each case study area: (1) assess current and future vulnerability of water resources to climate change; (2) identify potential adaptation strategies within a stakeholder-driven process; (3) formulate a pilot adaptation measure which has been identified as the highest priority option from the stakeholder process; (4) integrate the results into national policy discussions and legislative action.

Sadah Basin, Sana'a Basin, and the urban/peri-urban area including and surrounding Aden City were selected as representative case study areas. The location of each site is shown on the map below. The rationale for the selection of these particular sites was that each represented a different ecological zone and development context. This offered an opportunity to examine and compare various dimensions of vulnerability to water scarcity, as well as to explore a plausible range of potential adaptation strategies.

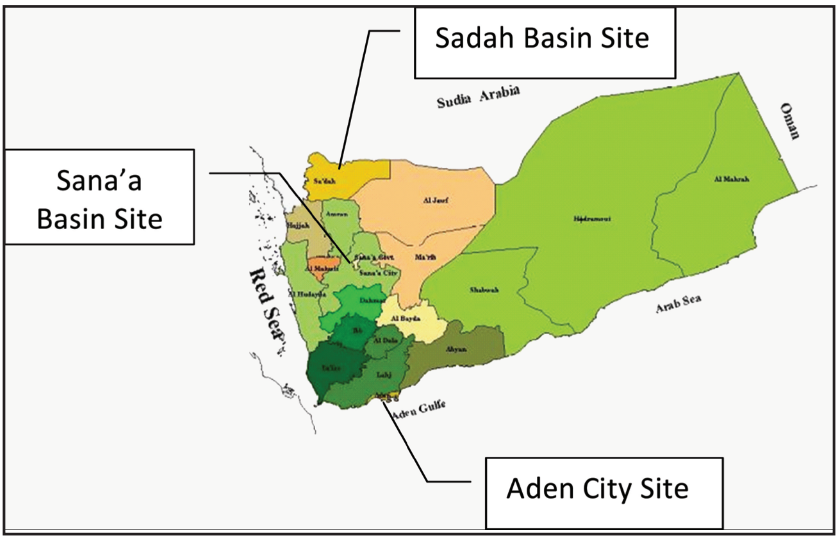


Figure 1: Case study site locations

There were four key project activities in each case study area: extensive stakeholder consultations; data collection; integrated modeling of water demands and supply; and multicriteria assessment to prioritize adaptation options. Stakeholder consultations were undertaken using rapid rural appraisal techniques and focused on local perceptions of water scarcity, climatic factors, and development challenges. These structured stakeholder discussions were synthesized into a set of inputs for water resource modeling and prioritization of adaptation initiatives.

Moreover, a wide range of data from national and international sources was collected and synthesized for each case study site (subject to availability constraints). This included information on poverty and social indicators, water use and resources, surface runoff, surface and groundwater availability, groundwater depletion and management, crop production areas, soil cover, maps, and meteorological information. As with stakeholder discussions, the output of this effort was a synthesized body of knowledge that fed directly into water modeling activities and the assessment of adaptation options.

Water balance modeling was used to evaluate water demands and scarcity across all sectors for each of the case study sites. The Water Evaluation and Planning (WEAP) software, a user-friendly modeling platform that takes an integrated approach to water resources planning, was used to document and simulate current and future domestic and agricultural water use demands, climatic and hydrological parameters, and groundwater declines. The WEAP model served as the framework for the analysis of both a reference scenario (i.e. water supply and demand in the absence of adaptation strategies and under a climate sequence developed by repeating historical climate data), supply and demand conditions superimposed on two possible future climate sequences developed from downscaled global climate model data, and a set of Alternative Scenarios, all simulated through the year 2025. These latter scenarios represented potential water resource management strategies, identified through stakeholder consultations, which have the potential to reduce the vulnerability of communities to water scarcity.

Prioritization of adaptation initiatives was carried out within a stakeholder-driven multicriteria assessment (MCA) process. An MCA is a structured approach to determine overall preferences of various interest groups (e.g. farmers, politicians) among alternative options, where the options can accomplish several objectives. Because the Yemen NCAP project took place concurrently with its National Adaptation Program of Action (NAPA) project, the NCAP benefited from the capacity already developed for the MCA within the NAPA process. The output of this activity was a ranked set of potential adaptation options.

3 Key Results and Findings

In this section, the key results and findings for the Yemen NCAP project are presented for each case study site following a brief overview of the physical and socioeconomic characteristics of each site. The discussion of key findings covers current vulnerability (based on available data and stakeholder consultations), future vulnerability (based on WEAP modelling), desirable adaptation options (also based on WEAP modelling) and a prioritized set of adaptation options (based on MCAs).

3.1 Sadah Basin

An intermountain basin, the Sadah Basin is situated in Yemen's western highlands about 250km north of Sana'a. The basin is characterized by sparse rainfall and high evapotranspiration rates. The plain is surrounded by mountains reaching 2,750m above sea level (ASL). Elevations in the plain itself range from 1,840 to 2,050m ASL, with gentle gradients towards the southeast where water collects in the Marwan Wadi, which flows northerly into the Najran Wadi. There are no permanent or seasonal streams and only after heavy rains will surface water runoff discharge into the Marwan Wadi. As such, there are no major flood risk areas.

In the late 1970s, and continuing to present times, socioeconomic development in the region emphasized irrigating agriculture with groundwater extraction from various aquifers underlying the region. This decision has had enormous implications for water scarcity in the Sadah Basin, as it has produced a gradual replacement of rain-fed agriculture with irrigated agriculture and aided rapid groundwater depletion.

3.1.1 Current Vulnerability

Understanding the current vulnerability of water resources in the Sadah Basin area relied on input from stakeholder consultations and existing studies. Stakeholders consulted included farmers, NGO representatives, and officials in key government offices. The information collected helped to identify causes of water use inefficiency, how people were responding to growing scarcity, and potential obstacles to adopting alternative water management practices. The primary finding of these studies was that the high current vulnerability of Sadah Basin water resources to climate variability and change, according to stakeholder testimony, is largely due to the current rapid depletion of groundwater, low efficiency of water use, low coverage of water and sanitation services.

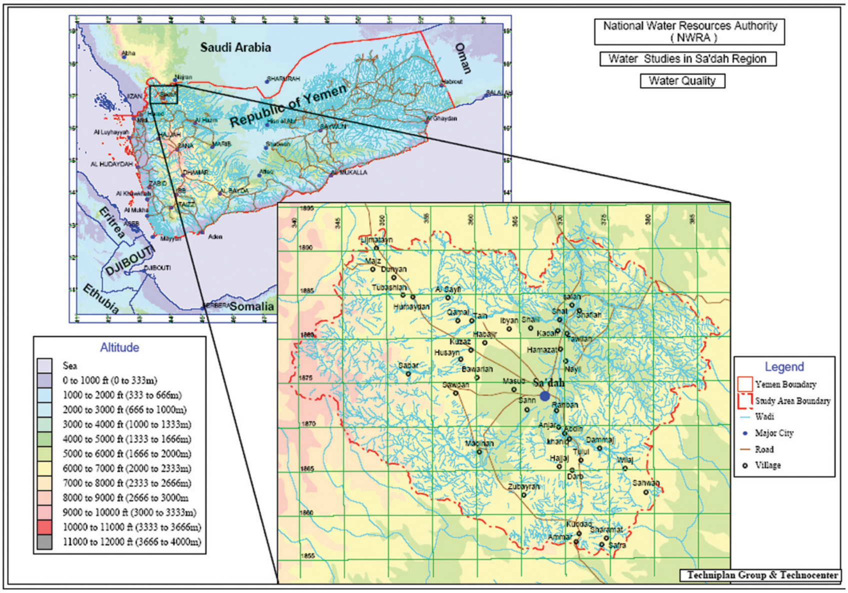


Figure 2: Water sub catchments of the Sadah Basin

While there were no specific studies on the vulnerability of water resources to climate change in the Sadah Basin, the YOMINCO/TNO (1983), the DHV (1992) and Techniplan/NWRA (2002) studies addressed the issue indirectly. The YOMINCO/TNO study mainly investigated water resources through geophysical surveys, a well inventory and aquifer tests. The DHV study updated the well inventory and investigated other issues related to water management, such as the socio-economic context. The Techniplan/NWRA study dealt with remote sensing aspects of the Sadah Basin and illustrated the dominant aquifers and aquicludes in the basin and outlined the most significant flow directions. Figure 2 summarizes the hydrology of the Sadah Basin based on these sources of information.

The combination of stakeholder consultations and available data was instrumental in establishing a baseline of information to understand current vulnerability. Between 1983 and 2001, the total groundwater extraction doubled. The doubling of the number of wells between 1983 (1,100 wells) and 1992 (2,330 wells), and again between 1992 and 2002 (4,989 wells) – coupled with improved well-design – increased gross groundwater extraction by about 30%. Whilst the farmers mainly exploit the groundwater resources of the Wajid sandstone aquifer; further groundwater depletion poses large economic risks to farmers. Farmers are concerned that not only are existing wells' yields continuously deteriorating, but water quality is also declining. Researchers found high rates of salinity and pollution from improper waste management were affecting the quality of well water.

Simultaneously with the above trends, groundwater recharge has declined. In 1983, net aquifer recharge was estimated at 10 million m^3. Between 1983 and 2001, total groundwater extraction grew from 45 to 90 million m^3/year while net aquifer recharge dropped to just 7 million m^3/year, or about a 30% decline from previous levels. By the end of 1998, the active zone of the aquifer had been exhausted.

In principle, Yemen's national water management plan is "basin co-management" whereby stake-holders and state institutions are considered partners in managing water resources at the catch-ments level. However, in practice the current Sadah Basin Committee is widely acknowledged to be ineffective. Attempts to establish more community-based water management organizations have been consistently constrained by limitations in the National Water Resource Authority's resources and on-site presence.

Regarding current coping strategies to deal with water scarcity, some water harvesting does occur for irrigation purposes. Compared to groundwater pumping, however, water harvesting is still a minor tool used by farmers. Moreover, there are no wastewater treatment plants, therefore reuse of wastewater (i.e. greywater) is not an option. In any event, overall stakeholder sentiment is critical of the notion of wastewater reuse as residents remain confused and skeptical of the potential benefits from a plant. This negative perception is related to problems experienced in other cities, e.g. the Sana'a wastewater treatment plant which most associate with pollution and odors.

3.1.2 Future Vulnerability

There are seven major hydrological sub-basins that have been identified using diagrams obtained from provincial reports as shown in figure 2. These sub-basins include Nushur, Razamat, A'kwan, Dammaj, A'lat and A'yn, Sabar and As Sa'id, and al Haniyah and A'wayrah.

Modeling of water supply accounted for groundwater and surface water resources. Groundwater for the entire basin was assumed to be 3,728 million m^3 of stored water based on available statistics for the basin. Four existing surface storage structures (i.e. dams to capture flash flood waters) having a combined annual capacity of 1.7 million m^3 were also modeled (i.e. dams on the Dammaj, the Sabar, the Nushur and the Marwan *wadis*).

Water demand was distinguished between agricultural and household demand. Agricultural water demand associated with irrigated areas was divided among the three major crop types: grapes (40%); cereals (30%); and wheat (30%). While other crop types such as vegetables and fruit orchards are cultivated in the basin, limited data availability hindered adequate modeling of these water demands. Domestic water demand was projected using historical population growth rates for the urban population of Sadah City and the disbursed rural population surrounding the city.
The reference scenario repeated historical climate data for the Sadah Basin through to 2026. Two climate change scenarios simulated the magnitudes of changes in precipitation and temperature; the OSU Core and the UKH1 dry scenarios[1]. The UKH1 serves as a worst case scenario in which annual precipitation decreases by up to 32% relative to the 1960 to 1990 baseline and that temperature would increase by up to about 2.2°C relative to the historical baseline by 2050. These assumptions were based on previous climate modeling work undertaken during the earlier NCCSAP program.

Without the identification and implementation of suitable adaptation measures, and assuming patterns of growth described above, the key finding of the Scenario analysis is that the aquifers underlying the Sadah Basin will be completely depleted by around 2024, essentially regardless of climate change. This is illustrated in figure 3 which shows full groundwater depletion virtually unchanged for the reference, OSU Core and UKH1 Dry scenarios. It is against this alarming conclusion that stakeholders and the research team consulted about potential strategies to mitigate or avoid this calamitous outcome.

3.1.3 Adaptation Strategies

In consultation with stakeholders in the region, three Adaptation Scenarios were developed to explore ways to reduce future vulnerability, as described below:

Improved irrigation efficiency: This adaptation scenario considered the introduction and aggressive penetration of drip irrigation techniques that dramatically increase irrigation efficiency.

1 Downscaled climate models from Global Circulation Models (GCM) for Yemen: OSU (Oregon State University GCM); UKH1 (U.K. Meteorological Office High Resolution General Circulation Model).

Increased storage capacity: In this adaptation strategy scenario, five new dams are added to the *wadis* starting in 2010, each with a 0.5 million m^3 storage capacity. These dams would be coupled with rain harvesting technologies to enhance groundwater recharge and increase rainfall runoff collection during dry months.

Greywater use: This scenario focuses on the construction and operation of a wastewater treatment plant with a capacity of 50,000 m^3/day for Sadah city. The effluent from this plant is available for use as agricultural irrigation in the Alat and A'yn sub-basin as well as for reuse in the city beginning in 2008.

A key finding of the Adaptation Scenario analysis is that, taken in isolation, none of the options is able to delay the depletion of aquifers underlying the Sadah Basin by more than a few years. The drip irrigation scenario avoids total groundwater depletion by only an additional two years relative to reference conditions; building new dams delays depletion by only one year; and the greywater use option has a negligible impact (due to the limited volume of water produced and stakeholders benefited). The failure of these options to forestall the ruin of the region's productive domestic and agricultural sectors merely underlines the urgency to consider multiple concurrent and/or more intensive options.

The adaptation strategies above fed into an MCA process in which the results were discussed with stakeholders in an effort to prioritize adaptation options. Of the initial three strategies, only the first two were prioritized as the use of treated wastewater was viewed as too limited in its ability to benefit a large section of the population of the Sadah basin.

Given the meager impact of each option applied individually, stakeholders advised the implementation of all three options concurrently. Figure 4b shows the additive effect of the adaptation strategies. That is, the red line to the right represents the combined effect of grey water, drip irrigation, and new dams. It is important to note that even this aggressive adaptation scenario is not able to stabilize annual groundwater demand relative to annual groundwater supply, and primarily serves to delay the inevitable groundwater depletion by only a few years.

The implications of this finding are staggering from a policy perspective. Achieving future water long-term supply/demand equilibrium in the Sadah Basin through the use of very aggressive targets for efficiency, recycling, and additional storage capacity is impossible. The failure to reconcile supply and demand suggests that the region is on the cusp of a major environmental disaster in the not too distant future. In other words, no matter the degree to which the capacities of regional water sector agencies are enhanced, or the rigor by which water demand mandates are monitored and enforced, it is too late for the region to achieve a sustainable water use trajectory through incremental improvements. That this situation exists regardless of climate change highlights the nature of the sustainable development crisis at hand in the region.

Other more intensive, more politically unpalatable strategies are likely to need exploring, and soon. These range from the very expensive (e.g. long distance water hauling) to the severe (e.g. strict water rationing for domestic use), to the draconian (e.g. relocation of existing communities). Exploring these sorts of options will be enhanced through seeking a goal of greater community participation in decision-making. Discussions of the Sadah Basin Committee and beyond would be more effective if all parties involved made a concerted effort to work together and avoid conflict, rather than acting individually.

3.2 Sana'a Basin

The Sana'a Basin is located in the Central Highlands of Yemen and includes the capital city of Sana'a. At an elevation ranging from 2,000 to 2,200m ASL, the basin is characterized by localized rainfalls with intense precipitation events of relatively short duration. Rainfall is the source of runoff in the wadis and of ground water recharge.

The Sana'a basin had a population of 2 million in 2004, constituting about 8% of the country's total population. It is important to note that Sana'a city is among the world's fastest growing cities, the population residing in the city itself is growing at about 5.5% per year and in the surrounding rural areas, the population is growing at about 3.2% per year. Population growth and subsequent increased reliance on groundwater extractions have led to a lowering of the groundwater table at alarming rates over the past 20 years. Existing government plans for expanding irrigated agriculture over the 2016 to 2020 period suggest this heavy reliance will only increase.

3.2.1 Current Vulnerability

Hydrologically, the Sana'a Basin can be divided into an upper (northern) unit referred to as the Wadi Al Kharid Hydrological Unit and a lower (southern) unit referred to as the Musyareka Hydrological Unit. On the basis of surface water drainage systems and topography, a total of 22 distinct sub-basins have been identified for planning purposes. There are six major aquifers in the Sana'a Basin: Northwestern, Northeastern, Central Plains, Eastern, Southwestern, and Southern. The urban area surrounding Sana'a draws water from the Central Plains aquifer.

Driven in large part by population growth, steady improvement in governmental services, and high system losses, water consumption in urban areas has increased from 57 million m^3 to 70 million m^3 between 1995 and 2000, which implies an average annual growth rate of 4.2%. In rural areas, beneficiaries of water supply projects have grown from 6.8 million to 7.7 million over the same period, implying an average annual growth rate of 2.5%. It is important to note that current water supply sustains probably no more than half the amount demanded, as there is substantial unmet demand in the region.

Trends in water consumption have put enormous strain on the basin's limited groundwater resources. Indeed, the Sana'a basin experienced dramatic declines in its groundwater table in recent years, a fact that has been cited by all stakeholders as the region's most pressing development challenge. In 2004 alone, the groundwater table dropped by about 7m in the eastern region and about 8m in the western region of the basin. These declines come in addition to water table declines of previous years, all of which reflect increasing access to groundwater in recent years.

The decline in groundwater is partially due to technological advancement. At one time in Yemen's distant past, traditional, shallow hand-dug wells (about 15m deep) were the norm and dotted the basin. In the 1970s, farmers began to deepen these wells up to 30m using locally available metal tools. In the 1980s, modern drilling techniques were introduced, enabling well depths between 200 and 250m that make use of diesel pumping systems. Today, most boreholes are more than 400m deep and the "water reservoir" continues to become further and further away from the surface.

3.2.2. Future Vulnerability

To assess future vulnerability of groundwater resources using a WEAP process, groundwater in the basin was divided into five major aquifer systems according to a characterization conducted by WEC (2001). These comprised the Central Plain, Southwestern, Southeastern, Eastern, and Western aquifers. Modeling the aquifer systems in this way made it possible to represent differences in groundwater storage and availability across the basin.

A number of assumptions were integrated into the reference scenario. Population growth in Sana'a city was assumed to continue at high rates, 5% per year through to the end of the planning period in 2026. Agriculture in sub-basins 9 and 16 (surrounding Sana'a city) was assumed to continue recent patterns of a decline of about 3% per year, and a 1% per year decline in sub-basins south of Sana'a. On the other hand, agriculture in the sub-basins north of Sana'a was assumed to increase by about 3% annually, consistent with recent patterns and government plans. In addition, the treatment capacity of the Sana'a waste water treatment plant (WWTP) was assumed to increase to 0.1 million m^3/day in 2012, consistent with expansion plans.

To gauge the impact of climate change on water resources in the Sana'a Basin, two climate change scenarios were developed to represent possible changes in precipitation and temperature; the OSU Core and the UKH1 Dry scenarios[2]. Compared to the reference scenario, basin-wide annual precipitation under the OSU Core scenario increases by approximately 17 million m^3, or 2%, by 2025. In contrast, annual precipitation decreases by as much as 73 million m^3 (approximately 10% of the reference scenario value) during the same period for the UKH1 Dry scenario. Temperature increases, relative to the reference, in both scenarios by an average of between 1.0 and 1.3°C for the OSU Core and UKH1 Dry scenarios, respectively.

The effect of these climate change projections on annual irrigation requirements and groundwater depletion are summarized in figure 5a, which shows that an observable impact of climate change on irrigation demand, however small. The effect of climate change on groundwater depletion (figure 5b) in the Central Plain aquifer, for example, is also very small; groundwater is depleted by the year 2017 under all of the climate trajectories explored in this study. Full groundwater depletion also occurs in the Eastern and Northwestern aquifers while the remaining three aquifers in the Sana'a Basin (i.e. Northeastern, Southwestern, and Southern aquifers) are, in comparison, not particularly vulnerable to projected future water supply/demand conditions as they show relatively stable storage capacities over time.

Without the identification and implementation of suitable adaptation measures – and assuming patterns of growth described above – the key finding of the analysis is that supply/demand patterns are the primary drivers of vulnerability. Climate change exacerbates this vulnerability, rendering water scarcity issues more acute, particularly regarding the need for additional irrigation.

3.2.3 Adaptation Strategies

Several adaptation strategies were developed and explored in the WEAP model for the basin, as briefly outlined below. It is important to note that not all of these options were simulated uniformly across all the sub-basins or aquifers. Several strategies were more localized in nature, informed by both physical and strategic considerations (e.g. improving water distribution systems is relevant for the urban area of Sana'a).

Drip irrigation: Improve irrigation efficiency by introducing drip irrigation techniques.
Improved indigenous methods for wadi flow use/infiltration: Simulate the impact of increased small dam construction as a means to improve *wadi* flow infiltration and decrease losses to evaporation. A 20% increase in the infiltration rate of *wadi* flow is implemented in 2010 in each of the major *wadis* in the basin.

Alternative crop production: Shift from qat production to a crop less water intensive and one that can enhance local food security. A 3% per year decrease in the areas cultivated with qat by replacing it with wheat was implemented starting in 2008.

Improved water distribution systems: Implement measures to reduce the high losses in the municipal water distribution system and introduce water saving fixtures on the demand side in sub-basin 16. This strategy is modeled in the WEAP by reducing the annual water use rate in Sana'a by 1% per year starting in 2008 and reducing losses in the distribution system from an initial value of 30% to 10% over the planning period.

2 Downscaled climate models from Global Circulation Models (GCM) for Yemen: OSU (Oregon State University GCM); UKH1 (U.K. Meteorological Office High Resolution General Circulation Model).

Promotion of lower population growth in Sana'a city: The population growth rate in this scenario is simulated as 2%, compared to 5% in the reference scenario.

Use of greywater: Use wastewater treatment plant (WWTP) effluent for agricultural irrigation requirements in sub-basin 9. In this scenario, treated wastewater is applied to irrigation areas rather than letting the water flow into the Al Khared *wadi*.

Under reference conditions, the groundwater situation appears sustainable, despite a drastic decline, when considering the basin aquifer storage as a whole, which levels off at approximately 65% of total groundwater storage at year 2020 and beyond (i.e. about 3.4 million m^3 in 2020 and beyond compared to about 5.2 million m^3 in 2007). However, when results for each of the six aquifers are represented individually, the disparities among trends in groundwater storage become apparent and pose major adaptation policy implications. Whereas groundwater storage in the Northeastern, Southeastern and Southwestern aquifers appears to be sustainable under the conditions simulated in the reference scenario, groundwater drops precipitously and becomes *fully depleted* in the Central Plains, Eastern and Northwestern aquifers over the time period studied.

For these three vulnerable aquifers, the adaptation strategies identified above were modeled individually to assess their potential role in stabilizing water demand. The options fail to substantially mitigate the calamitous nature of future water/supply conditions in the Central Plain aquifer within the study time period. The most efficient adaptation strategy only delays the full depletion of the aquifer by 5 years beyond the point of depletion in the reference scenario. Only when the strategies are superimposed (i.e. simulated together) do the aggregate water savings, with the addition of the final strategy (the use of treated wastewater effluent for irrigated agriculture in sub-basin 9;), enable groundwater decline to level off. Note though that with all six strategies in place, groundwater storage in the Central Plains aquifer still continues to decline with time, albeit far more gradually than without the measures. This indicates that additional measures would need to be implemented in order to produce a flat, or sustainable, groundwater storage trajectory. Though not shown here, the Eastern and Northwestern aquifers show similar patterns.

The effect of implementing the adaptation strategies on unmet demand shows clear differences regarding the effectiveness of individual options. Those strategies that are implemented in all of the sub-basins (e.g. the introduction of irrigation efficiency and, promoting improved indigenous wadi flow infiltration) rather than targeted on specific sub-basins (e.g. improving urban efficiency in sub-basin 16 and using WWTP effluent for irrigation in sub-basin 9) provide greater savings of total groundwater reserves.

3.3 Aden City

Aden City is the chief port of Yemen and is one of the largest natural harbors in the world with an area of about 70km^2 of sheltered water surrounded by Jebel Shamsan, Khoremakser, and the shore extending to the hills of Little Aden. With a population of almost 600,000 in 2004, it then represented about 3% of total population of Yemen.

Average annual rainfall ranges from 30mm per year to as much as 50mm per year. Weather patterns are driven by humid winds that run parallel to the coast without penetrating inland. Temperatures are generally hot with average temperatures ranging from 27 to 30°C (42°C maximum) and relative humidity ranging between 60% in the night to 80% in the early morning. The city is surrounded by mountainous areas in the south and a coastal plateau in the north. The region also includes a number of ancient *wadis*, such as the Alkhosaf *Wadi*, the Alaidaroos *Wadi* and the Altaweelah *Wadi* which are all located in the old town of Aden (Crater) where traditional cisterns have been erected for flash flood protection.

Like other areas of the country, Aden City is growing rapidly – about 3.8% annually. However, with no perennial rivers, the water supply system needed to meet the demands implied by this growth depends largely on groundwater in the Tuban & Bana Delta Basins, located outside Aden in the Lahej & Abyan governorates. While lacking in surface water, seasonal flash flooding is nonetheless essential for aquifer recharge through *wadi* bed infiltration and spate irrigation inflow to the main *wadis*.

3.3.1 Current Vulnerability

Aden City is currently highly vulnerable to water scarcity issues. As a growing urban center and a regional hub of economic activity, it is plagued by water consumption far in excess of available freshwater supplies. The most vulnerable communities are middle-income and lower-income households, particularly those in coastal areas dependent on agriculture. Yemen's Poverty Reduction Strategy Paper (PRSP) addresses the linkage between poverty and the environment, yet has not incorporated the potential impacts of climate change on these vulnerable communities.

Indeed, Aden City is in the midst of a water crisis. As no perennial rivers flow through Yemen, the city relies predominantly on diminishing groundwater supplies to meet its domestic, agricultural, and industrial sector demands. The only surface water available is from *wadis* near the Gulf of Aden that originate from rainfall in the southern escarpment of the country. The city depends on four well fields to extract groundwater, and in peri-urban communities groundwater is provided by an extensive system of wells. Groundwater sources are also located in other governorates, but accessing those supplies is a potential source of acute political tension.

Despite these constraints, existing economic development plans call for agricultural sector expansion as well as the attraction of foreign investment for industrial development. Without adequate planning, such plans are likely to be highly maladaptive due to the fact that groundwater resources, already heavily exploited, are constrained by weak natural recharge rates that depend on *wadi* bed inflow. While previous studies have identified sustainable extraction rates that would prevent future deterioration of water quantity and quality, by and large, these measures have not been implemented.

The water crisis that Aden City faces results from a number of interrelated causes. Overexploitation of groundwater results in an average drop of 1m in the water table per year. This overexploitation is driven by a combination of increasing population levels, entrenched poverty levels, and low distribution efficiencies. The domestic sector consumes 60% of available water – while commercial (12.6%), industrial (2.7%), and institutional (24.1%) uses account for the remaining 40%. There is also widespread structural collapses of old water wells, active and unplanned construction of irrigation wells, and serious water pollution associated with the increased use of fertilizers and pesticides.

3.3.2 Future Vulnerability

The WEAP model for the Aden area divides the system into two major sub-basins representing the Abyan and Tuban deltaic systems upstream from the city of Aden. These sub-basins comprise the ephemeral Tuban and Bana (Abyan) *wadis* which convey flash floods during the rainy season from uplands located outside of the model boundaries. A groundwater aquifer for each of these two sub-basins was included in the model.

Water demand was simulated for three urban centers: Aden, Lahej, and Abyan, which were given annual growth rates of 3.8%, 2.6%, and 2.4%, respectively, through the period of analysis to 2026. Additional urban infrastructure incorporated in the model included a wastewater treatment plant that serves Aden and discharges effluent to the sea, and a desalination plant with a capacity of 8.4 million m^3/day, but that due to cost, does not currently supply any water to Aden. Irrigation demand for agriculture was also simulated in each of the two sub-basins and for the peri-urban area around Aden.

Results for two climate projections based on the OSU Core and UKH1 Dry climate models were incorporated in the model. The OSU Core projection predicts a 10% increase in precipitation for the area by 2050, while the UKH1 Dry data projects a 16% decrease. The OSU Core climate simulation was assumed to be the "expected" level of climate change while the UKH1 Dry simulation captures a possible "worst case" drier climate trajectory. These projections were superimposed on a reference climate sequence that was based on historical precipitation values over the period 1952 to 1980. A simplified hydrological simulator was used for the Aden model due to lack of data availability for constructing models similar to those used for Sadah and Sana'a. As such, temperature was not included as a variable in this model.

The changes in precipitation represented by the OSU Core and UKH1 Dry climate projections had relatively small impact on groundwater resources in the two sub-basins surrounding Aden. Under reference climate conditions, both aquifers are nearly fully depleted by 2025, although depletion of the Lahej aquifer is more rapid (2015 compared to 2019 for Abyan) because of a greater reliance on groundwater compared to *wadi* flow in Lahej. The UKH1 climate projection, for example, shifts the point of depletion only several months earlier in Abyan and no substantial shift is observed for Lahej.

3.3.3 Adaptation Strategies

Several adaptation strategies were developed and applied in the Basin EAP model for comparison study as briefly outlined below.

Desalinization: This strategy involves supplying Aden city with desalinated water from the Al-hiswa hydropower plant at a capacity of approximately 22,000 m^3/day.

Improved irrigation efficiency: Enhancing irrigation efficiency can be accomplished by several means: implementing drip irrigation technology; conveying irrigation water through plastic piping, and rehabilitation of traditional earth and sand irrigation channels used with spate irrigation methods to transfer surface and groundwater to fields.

Use of greywater for recharge: With this strategy, treated wastewater from the Aden wastewater treatment plant would be injected into the Lahej aquifer. This strategy would provide an effective method to store treated water before use, minimizing evaporative losses of the treated wastewater. It would also involve injecting treated wastewater from the Abyan and Lahej wastewater treatment plants (planned to go into operation in 2009) into the Abyan and Tuban aquifers.

Use of greywater for irrigation: This involves the direct use of treated wastewater from the Aden wastewater treatment plant for irrigation in the Lahej catchment area. This water would be stored in a surface container while awaiting use. It would involve the direct use of treated wastewater from the planned Abyan and Lahej treatment plants for irrigation in the Lahej and Abyan catchments.

Improved water distribution systems: Distribution system losses for the urban centers of Aden, Abyan, and Lahej would be reduced in this scenario. Initial loss rates of 34.2%, 33.1%, and 33.8% for Aden, Abyan, and Lahej, respectively are decreased by 2.5% each year in each of the city starting in 2007.

The adaptation strategies simulated aid in mitigating depletion of the two aquifers on which the Aden, Lahej, and Abyan urban area and surrounding agricultural areas are dependent. For the Abyan aquifer, use of improved irrigation technologies (here, a 25% saving from drip irrigation is represented) mitigates groundwater depletion much more so than all the other strategies, which shift the time of full depletion by only several months.

In contrast, two strategies provide similar levels of improvement to groundwater storage in the Lahej aquifer: improved irrigation technology (again, the 25% savings from drip irrigation is represented), and either re-using or recharging Aden wastewater. The improvement due to re-use or recharge of Aden wastewater is substantial compared to the Reference condition where wastewater (WW) is discharged directly to the ocean. Therefore, in the "WW Re-use" and "WW Recharge" scenarios, the treated Aden wastewater becomes an additional source of water for meeting demands – a source that is not available in the reference scenario.

Implementing all strategies in parallel benefits the Abyan aquifer more than such a plan would benefit the Lahej aquifer. For the Abyan aquifer, the cumulative impact of all strategies results in a sustainable trajectory, while for Lahej aquifer, storage continues to decline, although much less dramatically compared to the reference condition. Note that for this comparison, only one permutation of wastewater use (recharge to the aquifer) was included because the scenarios were developed with the intent of simulating either re-use or recharge, but not both occurring simultaneously. Including both permutations would erroneously double the water savings from use of wastewater.

4. Lessons Learned and Strategic Recommendations

The choice of adaptation strategy depends on the dictates of the particular case study region, including both physical and stakeholder inputs. While pilot adaptation measures were not implemented as part of the effort, considerable effort was spent on scoping out the highest priority pilot scale adaptation for each area with help from local institutions. Using an MCA analysis among local stakeholders, the highest priority initiative was identified in each area as an input to future planning efforts. The scoping effort included a sequenced plan for implementation and monitoring of the initiative as well as a cost estimate for required materials and labor. A brief summary is offered below.

Sadah Basin: Drip irrigation and building small dams were identified as the highest priority initiatives, with drip irrigation preferred from a long-term perspective, especially for drought conditions. Monitoring of the effectiveness of the initiative would be based on rapid rural appraisal techniques carried out in conjunction with local institutions and government extension offices. Even with strong local support for these initiatives, they will be insufficient to stop full depletion of the aquifer in the near future under reference scenario assumptions.

Sana'a Basin: Stakeholders identified improving indigenous methods for *wadi* flow use as the highest priority initiative. The farming communities along this *wadi* are well aware of the need to harvest *wadi* storm flows. The area is littered with small structures in varying states of disrepair designed primarily to divert spate flow onto adjacent land to replenish soil moisture and groundwater. Approximately 23 check dams would be constructed on the main watercourse of the Asser *Wadi* watershed to reduce runoff flow and to enhance groundwater recharge.
Aden City: The implementation of drip irrigation was identified as the best strategy in terms of water savings both in terms of distribution and application of water on farmlands. This strategy was preferred by stakeholders over others, but is more expensive. As the majority of farmers are poor and barely coping with existing living costs, subsidization or donor support would be needed for implementation.

The key lesson learned from the study is that Yemen will continue to suffer from a pressing water crisis in the absence of strategies to stabilize water supply and demand patterns. Of particular note is the fact that climate variability and climate change is less influential than current and predicted patterns of agricultural and household water consumption. At the present time, annual withdrawals from groundwater resources exceed renewable resources by wide and unsustainable margins, and are likely to continue into the future without a vigorous policy intervention. Indeed, the analysis in the NCAP project has revealed that a collapse of water supply systems is likely to take place towards the end of the next decade in several important aquifers suggesting that timely interventions are urgently needed. At the technological level, improved efficiencies through drip irrigation and improved water distribution systems will have demonstrable effects when combined with other supporting adaptation initiatives.

The key strategic recommendation is that the time has arrived for water crisis management planning in Yemen. The situation in the Sadah Basin illustrates the critical nature of the looming collapse of waster supply systems in all but one of the basins in the country. For these locations, as the analysis for Sadah has demonstrated, conventional approaches to adaptation will not be sufficient. As a first step, efforts need to be undertaken to systematically identify all such basins and characterize them relative to remaining exploitable water resources and business-as-usual consumption projections. Secondly, a crisis-level set of strategies should be formulated and analyzed relative to costs, benefits, and level of community hardship implied. With this information in hand, Yemen should codify such options into a robust, sustainable water development strategy, amenable to international donor support.

Annex – List of Outputs

- Yemen – Workplan
- Yemen – First progress report
- Yemen – Second progress report
- WEAP modeling applications for each case study area with developed scenarios detailing the relevant future water balance projections and possible adaptation strategies
- Synthesis report of current vulnerability, livelihood and hydrological issues in the Sadah case study area, including findings of stakeholder consultations and relevant data collected
- Synthesis report of current vulnerability, livelihood and hydrological issues in the Sana'a case study area, including findings of stakeholder consultations and relevant data collected
- Synthesis report of current vulnerability, livelihood and hydrological issues in the Aden City case study area, including findings of stakeholder consultations and relevant data collected
- Synthesis report of current vulnerability, livelihood and hydrological issues in the three case study areas, including findings of stakeholder consultations and relevant data collected
- Analysis of future vulnerability, livelihood and hydrological issues in the Sadah case study area, including findings of stakeholder consultations and relevant data collected
- Analysis of future vulnerability, livelihood and hydrological issues in the Sana'a case study area, including findings of stakeholder consultations and relevant data collected
- Analysis of future vulnerability, livelihood and hydrological issues in the Aden City case study area, including findings of stakeholder consultations and relevant data collected
- Synthesis of future vulnerability, livelihood and hydrological issues in the three case study areas, including findings of stakeholder consultations and relevant data collected
- Synthesis of stakeholder-driven MCA results, including formulation of pilot adaptation initiatives in the three case study areas

Conclusions

Geoff O'Brien, Tahia Devisscher, Thomas E. Downing, Ian Tellam

Introduction

Much of the early work on climate change (related to adaptation) focused on prospective impacts: "what if" studies of the potential impacts of climate scenarios on resources. The starting point for the studies in this volume under the Netherlands Climate Assistance Program (NCAP) was current vulnerability and people's livelihoods. The assessments progressed to understanding adaptive capacity, embedded in social and institutional modes of resource management. Entry points for defining country studies in the NCAP were differential social vulnerabilities and poverty alleviation strategies, reflecting shifts in the wider community towards a more grounded vulnerability science.

Poverty alleviation is an integral part of development if individual and community well-being is to increase. Poverty is not just defined by crude measures of daily personal income, although global comparisons using such data are illuminating. Poverty is defined locally in Bolivia as "having no friends"; in Ghana as having no "ancestral connections"; in India poverty is about "not being free from the vices of greed". Poverty is not just a state but also a process of social relationships which are constructed in order to survive. Traditional extended family and social network obligations and entitlements are built and eroded as everyone is drawn into the global market place.

In poverty, people face the "vagaries of nature", and more so as extreme weather events increase as an outcome of climate change. Development seeks, among other things, a natural environment that is more uneventful. Ironically it does this most effectively when it enhances both natural and social systems' diversity. Diversity is key to building resilience; social diversity is key to building community resilience.

In trying to build a series of studies that link adaptation to poverty alleviation and development, particularly through Poverty Reduction Strategies (PRSPs), the NCAP managed to drive the adaptation process forward reaching a point where issues of resilience in development began to arise. Interestingly enough, resilience success gives a positive feedback to questions of impacts and vulnerability, coming back to the initial starting point of climate adaptation. This process (see Figure 3.1) which we call the "adaptation continuum" will be discussed in detail in this chapter and illustrated with key messages and examples from the country studies.

The first stage in the "Adaptation Continuum" is:

- Impacts to Vulnerability: from "what if" studies of future climate scenario impacts to understanding present vulnerability; who is exposed to what, where, when. This progression had already been well established at the outset of the NCAP projects.

Three further key stages in the Adaptation Continuum are:

- Vulnerability to Adaptation: shifting the focus from current exposure to processes of adjusting to current, expected and potential resources and risks.

- Adaptation to Development: embedding climate adaptation in development planning, recognizing the complexity of multiple stresses.

- Development to Resilience: viewing adaptive management as a process of ensuring the resilience of development pathways.

Our proposition of an "Adaptation Continuum" is consistent with the principles of climate adaptation as a socio-institutional process rather than the outcome of scenarios of vulnerability with some anticipated adjustment. This process-based understanding is in stark contrast to the static view of adaptive capacity as a snapshot of status indicators such as GDP per capita.

Figure 3.1: The Adaptation Continuum

From Vulnerability to Adaptation

The central focus of the NCAP is on the most vulnerable, primarily those people living in poverty conditions. Much of the literature recognizes that reduced crop yields, expanded zones of vector-borne diseases, sea level rise and other effects of climate change will affect the most vulnerable, as the poor have the least capacity to adapt.

> **Adaptation is all about livelihoods, how to survive while natural resources are becoming scarce.**
> *Mali Team*

The key question regarding adaptation scope or coverage has to do with what matters to those who are most vulnerable to climate change impacts. Developing a framework to better understand the coverage needed in the shift from vulnerability to adaptation, concerns metrics of impact that focus on the direct effects on community or household assets. In other words, it involves considering what is at risk and what/how much is potentially lost. This is particularly true when thinking about financial, institutional, and social assets currently enjoyed but increasingly at threat without appropriate adaptation interventions. What matters in terms of developing adaptation measures are the livelihood assets that characterize the Sustainable Livelihoods Approach; namely financial, social, physical, personal and human. Adaptation solutions need to relate to these assets. Consequently, the scope or coverage for this transition segment of the "Adaptation Continuum" (i.e. from vulnerability to adaptation) implies careful consideration of the specific assets at risk. This understanding underlies the project design of all countries that took part in the NCAP.

In adaptation, scale is a paramount issue. At what scale, local, regional, national or international, should adaptation processes take place is a challenging issue. While an impact assessment is limited to one scale, the NCAP shows that adaptation processes take place across different scales. Yemen provides a clear example of this challenge. In one region, the depletion of groundwater resources is so rapid that even if a full range of adaptation measures were implemented, it is unlikely that the water resources will ever be able to recover. Consequently, local-level adaptations may not be possible, unless there is a shift to new activities, and both national and international strategies for reducing stress on the water system may need to be explored.

Moving the debate from vulnerability assessments to adaptation requires the application of different tools and methodologies that allow for the integration of information and concerns. The NCAP

> **The major activities of the project included local level studies on various bio-physical and social issues, demonstration of improved designs of fishing boats and houses, saline tolerant crop varieties, simulation studies and participatory vulnerability assessment exercises. Awareness building and sensitization of the communities and local administration have also been done through training workshops and meetings at the local level, in order to translate science into locally accepted adaptation measures.**
> *Bangladesh Team*

projects have used approaches that focus on social learning, stakeholder consultation and participatory rural appraisal. What has been learned is that there is no single methodology as there is a range of problems that need to be tackled. This is expressed in the way the projects have used different sets of tools and methodologies to address country-specific vulnerabilities. Bolivia, for example, adopted both a participatory and integrated approach to assess vulnerability and develop adaptation strategies for two sectors: human health and production systems. The country combined different methodologies and tools that considered bio-geophysical factors, local perceptions, organizational settings and traditional knowledge to build adaptive capacity and facilitate social learning for adaptation.

The shift from vulnerability to adaptation has prompted questions about the design and implementation of appropriate channels for linking data and information to the decision/policy making process. On the one hand, NCAP projects have worked on improving data collection efforts (e.g. monitoring system in Bolivia), whilst on the other, it has been observed that data and information is available but is difficult to access and consequently rarely used (e.g. decentralized information system in Colombia where information is disseminated in different organizations that could collaborate more effectively). A number of projects have tried to solve this problem by developing information management systems. For example, Mongolia developed a database containing a range of information on adaptation projects and vulnerability assessments in the country, and Colombia developed a web-based application where GIS-based information is available for public use.

> **Science is necessary to seek adequate solutions of adaptation by acknowledging the vulnerability and identifying options or measures of adaptation to be implemented. But we need concrete actions, because people are victims of climate hazards, so science has to be action oriented.**
> *Senegal Team*

Perhaps the most critical element in the vulnerability to adaptation stage is the integration of the obtained outputs in the political or policy dynamic. It makes little difference to apply methods and tools to identify the most suitable adaptation initiatives, or to develop innovative communication protocols to transfer the results to decision-makers, if these activities do not result in concrete outputs supported by budget lines, new legislation, and/or leverage of new financial sources. Affecting the political and policy dimensions must be the ultimate test of efficacy of the vulnerability to adaptation process. Several countries have continued to produce substantial materials after the NCAP process ended, for example Ghana, who are consolidating social learning in their individual national context.

Integrating the outputs in political and policy dynamics requires engaging politicians through lobbying, mobilizing public support through information campaigns and steering the attention of powerful ministries (i.e. finance ministry and planning ministry) towards these outputs. Also, to effectively engage and affect the political and policy dimensions, questions about who is responsible for the implementation and management of adaptation projects/strategies in the country need to be considered. For example, Mongolia and Suriname have proposed the establishment of a new and separate political body for overseeing adaptation policies. Alternatively, Vietnam proposed to integrate those responsibilities into existing bodies.

Finally, measures that are generated in the vulnerability to adaptation stage cannot be viewed in isolation. The consequences of an adaptation strategy may influence and affect sectoral policies, livelihoods and so on. There is a need to reflect upon an adaptation strategy and provide feedback in order to integrate it into a broader context of development. The following section provides further insight on the process of integrating adaptation and development.

Adaptation and Development

All of the NCAP projects have deepened the understanding of the transitions and linkages between adaptation and development. These linkages are often interactive: adaptation actions based on vulnerability assessments are entrained in development planning; similarly development planning demands specific information on climate adaptation strategies and measures. Not all countries were able to move directly to this sort of analysis, suggesting that successful navigation of the transition from impact to vulnerability assessments and then to adaptation, is a critical step in moving economies and livelihoods towards more resilient positions. Nonetheless several activities undertaken by the NCAP projects were able to integrate adaptation into development processes. Some were able to move into a new paradigm of increased resilience (see the next section).

> **NCAP projects are responsible for promoting positive public awareness concerning climate change and public awareness in return contributes greatly to the increasing adaptive capacity of the country at all levels.**
> *Mongolia Team*

Trying to move the adaptation agenda into development planning requires the adoption of a new perspective. In many senses, the adaptation-development perspective is somewhat parallel to successful pre-disaster planning, but pre-disaster planning itself has rarely managed to engage with the development agenda. While there has been continuous discussion of the relief through development continuum, the debate has treated pre-disaster planning and development as separate entities, instead of focusing on their synergies and potential contribution to effective planning. A successful adaptation-development agenda could substantially reduce the cost of emergency disaster assistance. In the event of simultaneous disasters, increasingly likely as climate change accelerates, the increased demand on national and international disaster relief bodies could overwhelm local coping capacity. Self-reliance realised through effective pre-disaster and adaptation planning, as an integral part of development and aimed at capacity building for the most vulnerable, is a more effective means of disaster risk reduction. This approach builds resilience to respond to, and recover from climate change impacts, and is more effective than a reactive post-event approach. Strategies for adaptation to climate change combine relief, reconstruction and rehabilitation, seeking to promote sustainable conditions and self-reliance.

Integrating adaptation into development planning broadens the metric of impact beyond direct effects (e.g. economic damage and lives lost) to development targets related to health, social and economic effects (e.g. morbidity, livelihood security, economic investment and growth). The core metric is one where the reduction in mortality and morbidity are measured together with a reversal of the loss of livelihoods. The coverage in this transition can be defined, for instance, by the close interdependence between primary production systems, subsistence livelihood strategies, climatic conditions, food security, and income generation. In this sense, the impacts of climate extremes such as droughts, floods and heatwaves are measured not only by how much is lost but also by the effects on development and livelihoods of people that depend on primary production for their subsistence. It is important to bear in mind that climate factors are not the only factors that stress subsistence systems. Issues of markets, subsidies, access and cultural norms add to the challenge of assuring food security and alleviating poverty.

> **Results and outcomes of NCAP case studies can serve as a concrete base for developing and implementing future plans and programmes for climate change and adaptation for the vulnerable sectors.**
> *Yemen Team*

In Tanzania and Bolivia, NCAP climate change adaptation activities were linked to development, including increasing the robustness of primary production. In Tanzania, increased climatic variability was not solely responsible for the decrease in coffee production in the Kilimanjaro region: factors such as the decrease in operating capacity of farmer cooperatives and lower market value for the crop contributed to coffee decline, illustrating the complex dynamics of primary production systems. Improving the robustness of coffee as a cash generating crop could allow for increases in adaptive capacity to future extremes in climate, by contributing towards income stabilization and risk management. These activities can be considered as both a development and a climate adaptation strategy.

In the Lake Titicaca region of Bolivia, subsistence systems are based mainly on potato and broad bean production. Local perceptions identify climatic hazards such as more frequent droughts and frosts as some of the most important pressures affecting productivity that negatively impact food security and income. To better adapt to climatic hazards, municipal-level adaptation strategies focus on increasing the robustness of production systems. On the one hand, improved crop varieties were introduced and better production practices implemented, whilst on the other hand, agro-ecological activities (e.g. soil conservation) were adopted to allow a more sustainable use of natural resources. The implementation of these measures has the potential to improve income, decrease exposure to climatic hazards and enhance adaptation. Similarly, in the Vallegrande region, municipal-level strategies were aimed at protecting subsistence systems from flooding through the reforestation of upper portions of the watershed areas, combining development and adaptation strategies to protect and enhance primary production.

Previous projects implemented in Mongolia are mostly based on the top-to-bottom approach. However, this time we took into consideration the rural people's livelihoods and implemented bottom-to-top approach while keeping track of socio-economic components. Therefore, the impact was estimated by combining both directions and this was helpful to understand crosscutting issues.
Mongolia Team

To facilitate interactions and interplay between development and adaptation, both bottom-up and top-down approaches are needed. In Mali, water management is a critical concern. One study focused on community-level water management strategies that could protect local populations from risks posed by drought. The study identified several promising measures that will provide safeguards from potential future climatic and hydrological conditions. Another set of studies looked at water management strategies that could be implemented at a regional-level in river basins and aquifers. These strategies involved the construction of dams and other infrastructure that also exhibit positive future prospects. Both approaches highlight that adaptation is a multi-scale process that can interact with development efforts at different levels. One interesting question raised by the multi-scale nature of adaptation and development is how to reconcile the impacts and effectiveness of local-level action with that taken on a larger scale.

One method to reconcile this issue of scale and action in water management is the emerging Integrated Water Resource Management (IWRM) toolkit. IWRM brings to the attention of multiple stakeholders important issues such as water supply and water quality within a river basin, leading to a participatory policy and decision making process for water resources. In Guatemala, IWRM principles for river basin planning are part of the national policy to decentralize management of this critical resource to local authorities. As a result, several policy and decision making processes applying the IWRM principles are underway. The NCAP team, after making an inventory of processes related to water management in the Rio Naranjo system, was able to identify negotiations where climate change could be a relevant consideration. For example, climate change considerations were taken into account in regional negotiations to set water quality standards and to design wastewater treatment systems by providing insights into how climate change could alter the quality of water. This process lead to the integration of climate change effects into water management plans in the Rio Naranjo system. A further extension of IWRM is to incorporate adaptive management principles, important in adapting to uncertainty and potential tipping points.

Integration of adaptation measures across physical scales in water management, or in any other sector for that matter, needs to nest within national socio-economic considerations. NCAP partners in Suriname attempted to implement a nationally integrated approach by focusing on climate change implications on coastal planning, public health, water resources, agriculture and civil infrastructure. Efforts to integrate these different sectoral assessments focused attention on the importance of the main coastal road that links the capital and the majority of the population in the country. Integrated adaptation focused on defining coastal management strategies that protect this infrastructure to assure adaptation and development of the national socio-economic system.

Linking adaptation and development requires an understanding that off-farm income is critical to livelihoods and overall adaptive capacity. In Senegal, NCAP activity sought to understand climate change implications in non-primary production by looking at broader economic activities such as tourism and road transportation[1]. Tourism is a major foreign exchange earner and a generator of off-farm income. The primary focus of tourism in Senegal is the coast and this is threatened by sea level rise in the long term and by storm surges in the short term. Designing adaptation strategies for this sector is critical to both the national economy and off-farm income generating opportunities for subsistence communities. Similarly, road transport capacity is a critical service for subsistence communities as it provides access to markets for both supplies and products. Key elements of the Senegalese road network are threatened by sea level rise. NCAP efforts to design adaptation strategies have the potential to contribute to overall economic adaptive capacity.

The efforts in Senegal to integrate adaptation into the broader economy are noteworthy, as is the case of a sector-to-sector framework. To make progress towards resilience, however, cross-sectoral analysis is necessary. The most compelling example of integrated cross-sectoral development and adaptation analysis took place in Ghana. Analytical tools were designed and used in Ghana to assess the interactions of multiple adaptation strategies and their implications in national development policies. This fully integrated approach is the most effective means of minimizing maladaptation, where actions in one sector can have negative impacts in another. This aids effective resilience building in long-term national development processes. The next section discusses the transition from development to resilience in more detail.

Development to Resilience

The development to resilience transition starts with the recognition that entitlement negotiations and good governance are essential departure points for sustainable development strategies. From embedding adaptation strategies in development, this next transition is to a development pathway that is resilient to a wide range of threats and events, while protecting the poor and most vulnerable. The key characteristics of enquiry are to improve coping mechanisms across a range of traditional and modern adaptation technologies, together with an analysis of community and socially centred bounce-back structures that ensure recovery and continuation of the development trajectory. Validation of the change to a development-to-resilience paradigm requires evidence that the negative impacts of adverse weather events and climate trends have been significantly reduced.

Development and, in particular, poverty alleviation seeks to reduce the adverse effects of the impacts of variable events by building resilience. Resilience building focuses on improving coping mechanisms and the capacity to recover from disruptive events. This is also termed as bounce-back ability. As diversity is key to building resilience, bounce-back ability is achieved most successfully when both natural biological and social

> **Creating ownership among stakeholders is essential for the success of any adaptation option.**
> *Yemen Team*

1 In Senegal efforts to integrate climate change adaptation designed to protect primary production activities (i.e. agriculture and community-scale water management) were the main focus of early climate change adaptation work leading to the development of the NAPA.

systems' diversity are maintained and enhanced. Together these processes will help in building livelihood capitals and entitlements. But the processes must be realized through negotiation. Negotiation should be seen as transparent and be led by the recipient. Imposed solutions will not work.

Resilience building requires a positive feedback process that reduces impact. Moreover, building bounce-back ability needs appropriate information sets, knowledge of the range, effect and cost of adaptation technologies (both modern and traditional), and access to technologies and recognition that technology, in the broadest sense, changes relations between people and between people and nature.

An enabling and learning environment for knowledge-based activities is fundamental to promote social resilience across a range of scales. Different settings can be more or less conducive to effective learning. Learning requires reflecting upon experience and considering individual's values and interest in the process of cognition and action. While "single loop" learning increases the skills of an individual in an activity, "double loop" learning begins to question the framework of assumptions and beliefs. It is this latter learning process that can be an instrument for change, and change can enable a paradigm shift. Reflection and an enabling learning context can allow for emerging knowing and new understanding. This builds social resilience. Table 3.1 highlights the change in understanding/structures needed to inform adaptive management for the planning of a new resilience paradigm and figure 3.2 highlights the temporal dimensions of the shift to resilience.

Table 3.1: Changes Needed for a New Resilience Paradigm

From	To
Isolated event	Development process and pathway
Risk is not normal	Risk is expected
Centralized response	Participatory adaptive capacity
Low accountability	Transparency and negotiation
Status quo restored	Transformation

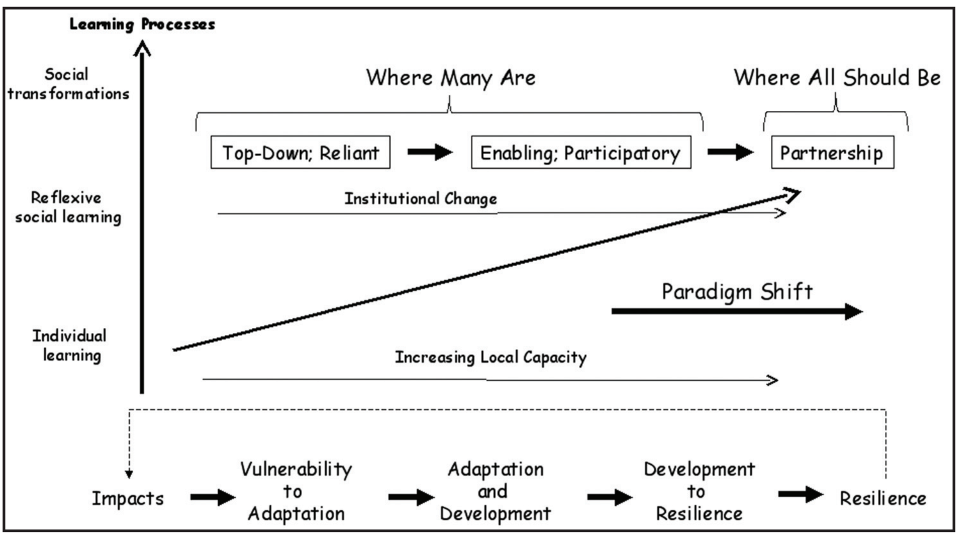


Figure 3.2: Dimensions of the "Adaptation Continuum"

The three main points sustaining this paradigm shift shown in table 3.1 are:

1) An understanding that the new paradigm is a dynamic process that has the quality to change and evolve over time;

2) The move from a top-down to a more bottom-up (participatory) approach is needed; and

3) The recognition that one perspective is not more credible than the other, but all perspectives need to be integrated into an enabling framework.

Implement a positive approach. A positive approach entails focusing mainly on the capacities rather than on the vulnerabilities and problems. The existing capacities can be part of the solutions to face the challenges. A positive approach can therefore contribute to find potentials and opportunities for development. In this sense, resilience can be considered a positive way of looking at the challenges of climate change.
Bolivia Team

The first point recognizes that development can never be risk-neutral and that all technological changes have risks associated with them. As such, it acknowledges that risk is "normal" and part of the development process as opposed to isolated events. Most importantly, this point recognizes that building resilience to climate change is a process that can change and evolve over time. This means that coping mechanisms should not necessarily seek to restore the status quo of a system, but should develop the capacity to adjust to new futures and new kinds of risks. One of the challenges that increased climate variability is bringing in the short to medium term, and climate change in the medium to long term is the challenge of "produced unknowns". Though the likely outcomes of a rapidly changing world, driven by a shifting climate are broadly known, the actual outcomes cannot be predicted with any precision. This is particularly relevant at the local-level where impact science has only produced a broad brush or sector focused output that is restricted by time. Responding to produced unknowns is a challenge that can only be addressed through strengthening coping capacity in ways that enable it to be flexible and adaptive to the variable challenges it will encounter. For example, the focus on environmental management that Colombia adopted in the NCAP project incorporated this thinking, recognizing that coastal natural system resilience is a dynamic process and mechanisms to enhance it and reduce potential impacts will probably change over time.

The second point supports the shift in understanding resilience from an outcome-oriented perspective, which is essentially a top-down and centralized approach that often lacks accountability; to adopting a process-oriented approach that allows for participation, learning, and bottom-up processes. The process-oriented approach has its focus not on needs and vulnerabilities, but on existing resources and adaptive capacities. The Bolivia NCAP project explored this paradigm shift by adopting a participatory approach to develop adaptation measures based on local perceptions and knowledge, while supporting organizational and social learning to build adaptive capacity first in local communities and then at the national-level.

The third point acknowledges that while this paradigm shift is key in resilience building, it is important to keep in mind that both bottom-up/process-oriented and top-down/outcome-oriented practices are necessary in the process and need to be complementary. In short, a top-down enabling framework that encourages bottom-up resilience building is the most effective framework.

In short, the underpinning of resilience planning for adaptation includes sustainable development, risk avoidance, least cost intervention, organizational and social learning, and exploring environmental unknowns and tipping points that lead to catastrophic change that moves systems beyond the limits in which resilience can affect a recovery. Resilience planning should be normalized as part of the development process as an issue of social justice. In that sense, it must not be considered as an add-on effort but integral and the impacts of resilience planning must be measurable.

The NCAP was bound by its terms of reference to focus on capacity building, essentially providing information and assessments and the teams did not have resources (time being more important than funding) to implement development plans or to substantially create resilience. There is nevertheless evidence that NCAP activities have begun to influence development planning.

The "Adaptation Continuum" Framework

The NCAP contribution to taking the adaptation process forward reached a point where issues of resilience in development processes became more visible. The following diagram illustrates the progress made by the NCAP country projects in the adaptation continuum. Examples are provided to demonstrate models of good practice to advance in the process towards building resilience as shown in figure 3.3.

The shift from an impact science to vulnerability is a case of adding the social perspective, but the move from vulnerability to adaptation and development in the NCAP studies, is one in which social perspectives are understood as dynamic actor-network processes in addition to traditional vulnerability analysis, often based on bio-geophysical indicators. It is this shift in perspective that places people at the entry point, and prompts the process to integrate socio-economic development and adaptation to bio-geophysical impacts. This process will lead ultimately towards building resilience that requires a paradigm shift.

Institutionally, NGOs can function on a number of scales that allow a shift from impacts to vulnerability and effects of vulnerability to an adaptation focus at the local, national and international-level. The link between adaptation and development is mainly related to activities of national governmental institutions, and the transition from development to resilience is mainly achieved at the community-level. This denotes the complexity and continually changing nature of scale in the adaptation continuum.

The complexity of the scale of action in the adaptation continuum can be better understood when analyzing the sets of information required for the process. To assess impacts biophysical data sets are necessary, whereas vulnerability analysis requires the addition of social data to inform the system. The key characteristics of problem statements of vulnerability, which occur on different scales, are different from impact statements that are defined for specific places and scales. The impact of climate change is conditioned by the variability of vulnerability across space, social groups and economic conditions. Social mapping of vulnerability reflects how vulnerability can be simultaneously constructed in different scales and across time.

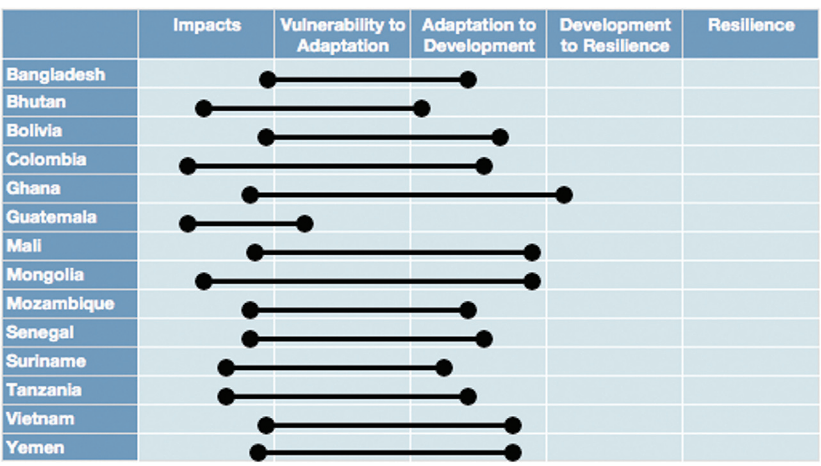


Figure 3.3: Progress Achieved by Projects Along the Adaptation Continuum

It is important to draw adaptation strategies from a wide range of traditional and modern interventions rather than take interventions from a single impact analysis that implies universality to adaptation that is not available. Building adaptive capacity requires moving forwards to consider actor-network dynamics. In this regard, the integration of adaptation and development needs to be informed by data on economic and institutional processes. Finally, moving from development towards resilience requires data that provides insight into coping mechanisms and a system to measure the positive feedback process of resilience that reduces climate change impacts.

Bangladesh

The major objectives of the NCAP project were to examine climate change impacts on fisheries and the agricultural sector, generate discussion on climate change and adaptation issues at local-level among different stakeholders and recommend possible adaptation measures through analysis of existing institutional arrangements and review of sectoral policies.

Bhutan

The Bhutan NCAP project focused on practical measures to reduce climate change-induced Glacial Lake Outburst Flooding (GLOF) risks from the potentially dangerous Thorthormi Glacier Lake. The work plan involved procurement of various specialist technical hardware and software needed for data collection and analysis. The conclusions are to be integrated into Bhutan's national development planning.

Bolivia

The NCAP focused on participatory vulnerability and adaptive capacity assessments in the Lake Titicaca region and the Middle Basin of the Vallegrande Region. Six municipalities have now formally approved local strategies and have agreed to provide the institutional mandate and financial support for adaptation measures. The project team was also able to secure additional funding to finance 15 additional adaptation measures in the context of the Adaptation Strategy mentioned above.

Colombia

All around the coast of Colombia there is evidence of flooding during annual storm surges, never previously monitored. In the short term this means that people are likely to be hit by an increasing number of disasters in the coming years. The Colombian NCAP project developed a framework linking local-level strategies and national-level policies and has supported the national decision making process in relation to the reduction of climate change related risks.

Ghana

The NCAP funded project in Ghana addressed: human health; fisheries; land management; and agriculture (with emphasis on cocoa production and root crops such as yam, cocoyam and cassavas). Sectoral vulnerability and adaptation assessments explored vulnerability in relation to a set of climate change scenarios (changes in temperature, precipitation etc.), and proposed adaptation strategies to build resilience against threats associated with climatic variability and change.

Guatemala

The NCAP identified the eastern area of Guatemala as the most vulnerable to the impacts of vulnerability and climate change, especially droughts. The project facilitated an inventory of policy setting needed in selected river basins and assessed the potential to set policy on water management that incorporates adaptation to climate change. More capacity is needed to go from impact analysis to the formulation, implementation and evaluation of adaptation strategies.

Mali

The major problem that climate change raises for Mali relates to water availability. There are already shortages of drinking water for domestic needs and for agriculture and livestock and climate change is expected to exacerbate this problem. The NCAP project studied the impacts of climate change on corn and cotton production and also assessed the impact on water resources in river basins of national importance: the Baoulé and the Sankarani, for irrigated agriculture and hydro-electricity production.

Mongolia

The NCAP project in Mongolia focused on various aspects of the natural environment of rural households and how they might be impacted by climate change. The focus of the project was: assessment of climate change impacts on natural pastureland and evaluation of adaptation measures; vulnerability and adaptation analyses of water resources in rural areas; vulnerability of rural people to extreme climate events, with a focus on droughts and dzud; and comprehensive analysis of climate change impacts on food security and sustainable livelihood of rural people.

Mozambique

The Mozambique NCAP project aimed to highlight the vulnerability and adaptive capacities of local communities within the context of disasters, as well as reviewing institutional disaster management capacity. Technical adaptation overviews of agricultural and water resources have been produced. A technical report on floods and droughts has been undertaken and will form a general oversight of the work on vulnerability and adaptation that has already been undertaken in the field. The core theme that emerged is how to build local resilient capacity.

Senegal

The NCAP funded project in Senegal contributed to the country's National Adaptation Program of Action (NAPA) to identify priority activities that respond to Senegal's urgent and immediate needs with regard to adaptation to climate change. The NCAP supported investigations into climate change vulnerabilities in the transport infrastructure and tourism sectors and final adaptation project papers were provided for an addendum to the Senegal NAPA on file with the UNFCCC.

Suriname

The NCAP project focused on the impacts and vulnerabilities of two specific coastal areas: Greater Paramaribo and Wanica, where the main concentration of the population and infrastructure are found. The team also carried out detailed studies of the socio-economic and biophysical situation in the study area. This enabled the team to develop and formulate very detailed adaptation measures for preparing and adapting the livelihood activities to the potential impacts of sea level rise.

Tanzania

The Tanzanian NCAP project focused on the production of technical adaptation policy options based on the vulnerabilities and adaptive capacities of local communities. Fieldwork ended with a symposium with local actors and NGOs and was followed by a national survey of the impact of climate change on agriculture in Tanzania, by ecological zonnation. A key conclusion from the Tanzanian NCAP project is that, when considering adaptation options, it is important to differentiate between genuine adaptive measures and an expansion in coping mechanisms that are already in place.

Vietnam

The NCAP project in Vietnam carried out impact assessments that assisted policymakers at the provincial and local-levels in the development of sound adaptation policies and in mainstreaming climate change adaptation into the planning and decision making processes. The project worked towards the integration of climate change considerations into the Integrated Coastal Zone Management (ICZM) Strategy and Action Plans. The NCAP also helped climate change considerations to be adopted into the planning and development of the Chan May – Lang Co Special Economic Zone.

Yemen
The NCAP project in Yemen identified priority activities to build resilience against increasing water scarcity among vulnerable communities, sectors, and ecosystems. The project was carried out in Sana'a City (highly urban highland), Aden (urban coastal environment), and the Sadah Basin (rural highland). Three case study reports were produced that summarized current and future livelihood systems and hydrology in each of the 5 ecological zones through a review of existing literature to collect socio-economic and water consumption data, and consultations with stakeholder groups in the three case study areas concerning water stress issues.

The following framework in table 3.2 summarizes the "Adaptation continuum" features discussed above including insights provided in the previous sections on the metrics, the key characteristics, as well as good models of practice to help the move towards resilience.

Table 3.2: The "Adaptation Continuum" Framework

Process Impact	V to A Process	A to D Perspective	D to R Paradigm
Metric	Lives Lost	Mortality and Morbidity Reduced	Livelihoods, Entitlements and Governance
Key Characteristics	Problem Definition	Pre-Disaster Planning Integrated Sectoral Analysis	Improved Coping Mechanisms Bounce-Back Structure
Models of Good Practice	Integrated Natural Resources Management	Early Warning and Climate Risk Monitoring Systems	Cross-Sectoral Analysis Entitlements Equity
Information System Management	Biophysical and Social Data Social Mapping	Data on Economic and Institutional Processes	Data on Coping Mechanisms, Existing Capacity, System to Measure Reduction of Impacts

General Lessons Learned and Further Steps to Take

This book collated the products of developing country scientists and analysts. The different NCAP projects took adaptation processes forward based on the work conducted at the local, regional and national-levels in each country.

Country projects used different analytical frameworks and a range of methodologies and tools to develop adaptive capacity. The NCAP has demonstrated that there is no single methodology to move forward in the "Adaptation Continuum", mainly because there is a range of problems that need to be considered. One important point is that exploring adaptation measures does not need to be expensive to come up with no-regrets solutions. The case of the redesigned boats and buildings in Bangladesh demonstrates this.

When linking adaptation and development, it is important to analyze both primary and off-farm non-primary production activities, as off-farm income is critical to livelihoods and overall adaptive capacity. Moreover, it is critical to recognize that adaptation measures should not be viewed as stand-alone measures. They must be integrated into broader development processes. It is at this point that institutional barriers to this broader integration effort will need to be removed. To move forward in the "Adaptation Continuum", integrated cross-sectoral development and adaptation analysis can support the shift from development to resilience.

Assisting the governments with data collection, including establishing observation networks, data processing and publications (information dissemination), including training, use of methods and tools, etc. Promoting the communication between countries (south-south cooperation and north-south cooperation) should also get more attention at all levels.
Surinam Team

Furthermore, progressing in the "Adaptation Continuum" requires appropriate databases to build policy and stimulate institutional learning, as well as effective information management systems to raise awareness that will inform the shift to a new resilience paradigm. In this process it is fundamental to maintain an integrated approach that allows for scale of action complexity.

Furthermore, it was recognized during the NCAP that a lack of suitable indicators exist to measure progress in connection with climate change adaptation. So an investigation took place into the feasibility of setting adaptation targets in Bangladesh, Bolivia and Mongolia.

The investigation defined two broad approaches to adaptation target setting: i) outcome oriented targets, such as numbers of persons less at risk from food shortages over time; and ii) process oriented targets, such as the certification of key agencies for competency in climate risk management.

Bolivia concentrated on urban slums and was able to link sector-specific adaptation targets to poverty reduction and sustainable development objectives, related particularly to MDG7. Mongolia focused on setting targets related to the livestock sector. Bangladesh considered the agricultural sector (food security and ecosystem services and goods) and human health (sanitation services).

Bolivia and Mongolia used an assessment matrix to analyze institutional & political capacity in relation to disaster management systems. Bolivia also referred to climate models to establish an accurate picture of the risks faced. A scoring system was used by both countries to measure the development status of the benchmarks set. The Bangladesh team carried out a vulnerability mapping exercise to depict the economic, social and physical vulnerability within the country.

All three country teams worked with national and local stakeholders to determine the extent to which a target setting approach might gain widespread acceptance. Relevant stakeholders included low-level ministerial representatives, NGOs and representatives of the research community.

Bolivia included international-level groups, such as the UN and foreign development agencies participating in a government-created ad hoc working group on climate change. Mongolia engaged a range of national-level stakeholders and also interviewed local herders, using non-structured interview questionnaires. Bangladesh convened a national-level working group with a range of government agencies and NGOs.

Adaptation targets set by each country differ because different areas of focus were used. Bolivia set generic adaptation targets related to the MDGs and one country-specific target to achieve significant improvement in the lives of approximately half a million slum dwellers that are increasingly vulnerable to climate change.

Bangladesh set targets under four broad goals based on climatic impacts in different sectors. These are non-numerical and generic and are generally related to development goals and to some extent to sectoral interest (e.g. improvement of the drinking water system, strengthening of the agricultural sector); the targets are complimented by indicators to allow monitoring and evaluation.

Mongolia set non-numerical targets under six elements specific to livestock resilience. These cover institutional matters, pre-disaster and disaster-response planning, as well as integrated livestock and livelihood system management. The targets relate to both sectoral and national development goals. Mongolia also set finance-related targets including credit to individuals to diversify their livelihood, and insurance systems for livestock extended to all high risk areas. Mongolia also set specific indicators for each target to facilitate progress monitoring.

The countries participating in the adaptation targets investigation followed similar methodologies, particularly in connection with stakeholder participation and the use of vulnerability/resilience assessment matrices to identify "adaptation deficits" and potential areas of focus to build adaptive capacity and adaptation. Targets between the countries differ due to the different scope adopted by each country. However, a common methodology to set adaptation targets and metrics could be implemented if developed under a similar conceptual framework and scope, such as a specific geographic region or economic sector.

The overall conclusion of the adaptation targets investigation under NCAP was that target setting can help focus adaptation efforts on priority sectors/areas. It can also facilitate monitoring of the effectiveness of managed responses to the adverse impacts of climate change. Country projects in Bangladesh, Bolivia and Mongolia demonstrated that the process of setting targets facilitates the identification of priority sectors, regions and locations and provides ways to monitor the effectiveness of response measures.

Also, vulnerability and resilience assessments conducted by the country teams to identify capacity deficits and to set adaptation targets contributed to defining specific actions needed to build resilience. For example, Mongolia set targets for disaster preparedness in the livestock sector that should demarcate the specific actions needed to reach those targets and move forwards towards resilience. Likewise, Bangladesh proposed targets that form the basis for specific actions to improve sanitation facilities, increase food security and improve health conditions.

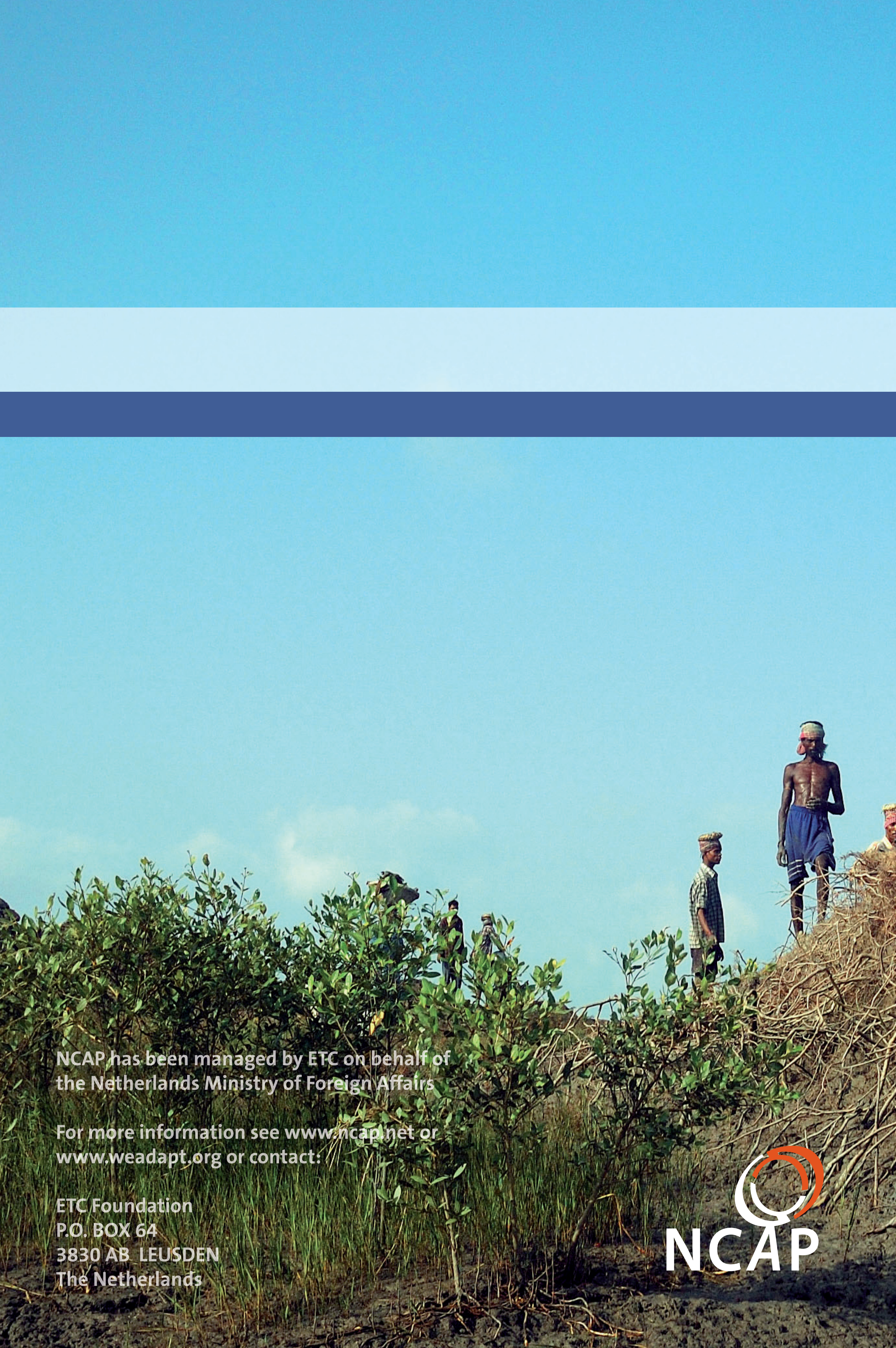
A further conclusion is that defining adaptation targets and metrics may also help to prioritize sectors, regions and locations for adaptation investments. This would be a natural progression in the case of the Bolivia and Mongolia projects, which focused on specific vulnerable regions and sectors respectively. In both cases, once implementation of measures associated with targets commenced, stakeholders would be compelled to determine the financial resources needed for specific problems in the identified areas.

All the teams involved in the NCAP adaptation target investigation agreed that the approach shows promise and suggested that pilot projects would help to gain on-the-ground experience.

In general, external assistance is needed not only for development of climate adaptation strategies, but for implementation as well. These assistances could be in terms of transfer of knowledge and technologies, training and capacity building, and providing required financial resources.
Yemen Team

The adaptation target investigation and the vast wealth of useful studies carried out in fourteen countries across three continents during the five years of the NCAP all show promise. However, addressing climate adaptation remains a challenge because any policy measures aimed at solving the climate problem will be effective only if they are integrated within a wider set of strategies to promote the efficient and equitable use of resources, good governance, investment and income growth. Meanwhile, developing countries typically lack the institutional capacity and financial means to carry out the range of activities that are needed to formulate, implement and evaluate such policies. Nevertheless, such countries contain many talented and committed individuals. This means that, with international support and cooperation, developing countries can carry out reputable science, as is demonstrated by the high quality of work produced by the NCAP country teams.

Perhaps the most important lesson from NCAP is that any attempt to utilize development planning to create resilience will require not only increased capacity but also greater political will. In short, stronger partnership and cooperation is needed to create an enabling environment that recognizes the role of all in resilience building. This is a lesson not only for NCAP, but for us all.



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